LIPPINCOTT'S PHYSIOLOGY

SECOND BOOK

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LIPPINCOTT'S PHYSIOLOGIES

THE SECOND BOOK

OF

ANATOMY, PHYSIOLOGY

AND

HYGIENE

OF THE HUMAN BODY

BY

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PREFACE

THIS is the second book of a three-volume series of physiologies. The first book is only for children. The third book is adapted to the needs of the highest grades of the public schools, including high schools. This second book is graded to the needs and capacity of intermediate grades.

Serious efforts have been made to present the various subjects in this book in a way that would make them plain and easy, and at the same time to teach some *real physiology*. A pupil may be interested and entertained without being instructed; but when interest is once aroused in the important facts of a subject, instruction is sure to follow.

The technical terms are used wherever needed. The *names* are not the difficult parts of a physiology. Technical styles of expression have been avoided, as they are not necessary

in a book of this character, and would only make an easy subject appear hard.

A number of experiments have been incorporated in the body of the text at points where they are most beneficial as an illustration. The live teacher will not omit a single one of these experiments, and will encourage the pupils to repeat the same and add others as far as possible. The experiments are an important part of this grade of work.

In regard to alcohol and narcotics, we have tried to present the truth as we see it, and as we have learned it from the research and experience of others. A broad view should be taken of this subject. In the light of the experience of the past, the nature of the substance in relation to the cells of the body, and the investigations of modern times, there appears to be nothing to recommend the use of alcoholic drinks as a beverage The matter is thus presented in this series of physiologies.

More cuts than are usually found in an intermediate physiology are given in this book. Good cuts that illustrate the text are very

valuable in this stage of the pupil's progress. A good text-book is always a little beyond the pupil, but the steps must be easy ones from what he knows to what he is striving to get. The cuts must be an aid in making these steps, or they may as well be left out. We have tried to have all the cuts in this book worthy of the space they take.

We wish to acknowledge our obligation to the J. B. Lippincott Company for many cuts which appear in this book.

Through the kindness of Ginn & Co. we were permitted to select two cuts from Blaisdell's "Physiology."

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SECOND BOOK OF PHYSIOLOGY

CHAPTER I

INTRODUCTORY

Matter.—All substances and bodies that we know anything about are composed of *matter*. Anything that we can see or feel is matter. Water, rock, air, wood, bone, iron, gold, and so on, are all forms of matter. Our bodies are made of various kinds of material substances which we take into the body by eating, drinking, and breathing.

Lifeless matter.—Lifeless matter is the kind that never moves or does anything of its own accord. Stones or wagons are lifeless because they will never move unless some outside force pushes or pulls them. The greater part of all the matter in the world is of this kind. The whole crust of the earth

and all the water and the air are lifeless matter. The wind blows only when the sun makes it do so, and it, in turn, may raise waves on the water.

A living body.—A living body is composed of matter, but the matter is made over and used by a force called *life*.

We can tell whether or not a body is alive, in three ways: (1) A live body can move itself. When a bug crawls along on the floor we are sure it is alive. A book will not do this. (2) A live body can take up lifeless matter and make it part of its own body. All live bodies must have some kind of food. In that way they grow and get strong. A stone does not grow or do any work. (3) All live bodies can start the growth of other bodies just like themselves. An apple-tree produces seeds which will sprout and grow up into other apple-trees of the same kind.

In short, then, all live bodies can *move*, *take in food*, and *produce other bodies of its own kind*.

Animals and vegetables.—All live bodies are either *animals* or *vegetables*. In some respects all live bodies are alike, but there are a number of plain differences between animals and vegetables.

A vegetable is fixed to one place on the ground, while an animal can move about. A vegetable lives on a very simple kind of food which it gets from the ground through its roots, or from the air through its leaves, while an animal can live only on vegetables or other animals. Animals can feel and choose, while plants have no such power.

The animals are a higher kind of living bodies than the vegetables.

Man's place among living bodies.—Man is the highest of all animals. His body is not so large or so strong as that of some of the lower animals, but he has the best brain, and so can know more than any other animal. A man can think, reason, invent, make plans, and prepare for the future. These things make man the master of all other animals.

Since this is so, we would think that all men would try to know all they could learn about their bodies and minds, and would be careful to observe the laws of good health.

Many people do not take as good care of their health as some of the lower animals do. Either they do not know any better or they are not willing to do what they should do. It makes no difference what the cause is, any one who does not obey the laws of health will have to suffer for it in some way.

Purpose of this book.—The aim in this study is to learn all we can about the human body. When we know how nicely the different parts of the body are made and joined together, and how well all the parts work for the good of the whole body, we will certainly try in every way to help them, or at least will do nothing to hinder them.

We will study this book, then, to find out the laws by which our bodies work, and then learn how to obey these laws so that we may have good health.

Why we should study physiology.—The human body, in one sense, is a machine. No one should try to run a machine unless he knows something about it.

If you were placed in charge of a printing-press, and were anxious to have it do the best kind of work for you for a long time, what would you do? No doubt you would carefully examine it to see how it was put together and what work each part had to do. You would run it in such a way that it would do the best kind of printing for you. You would keep it clean, well oiled, and not allow anything to get into the cogs and break them. If any accident should happen to the press, you would then know what to do.

We will study physiology for similar reasons. (1) To find out what the different parts of the body are. (2) To find out the use of each part. (3) To find out how to take proper care of the body.

The body composed of cells.—The body is made up of many millions of very

small bodies called *cells*. The cells are so small that they can be seen only with a good microscope. The flesh, the bone, the skin, the hair, and so on, are all made up of a great number of these little cells. In Fig. 1 the

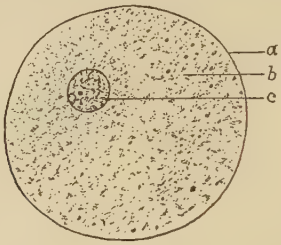

FIG. 1.—A cell. *a*, cell-wall ; *b*, albumin ; *c*, nucleus.

parts of a cells are shown. Within the cell, at some point, is always a *nucleus*. Around the nucleus is the *albumin*. Outside of all is the *cell-wall*. The nucleus is the centre of the life of the cell, and without it the cell would soon die. The albumin is a substance about like the white of an egg. It makes up the larger part of the cell. The cell-wall forms a little chamber, or cell, in which the nucleus and albumin are placed. In most vegetables this wall is thick and strong, but in animals it is often very thin or entirely wanting.

Forms of cells.—When a great number of cells are joined together to form a body

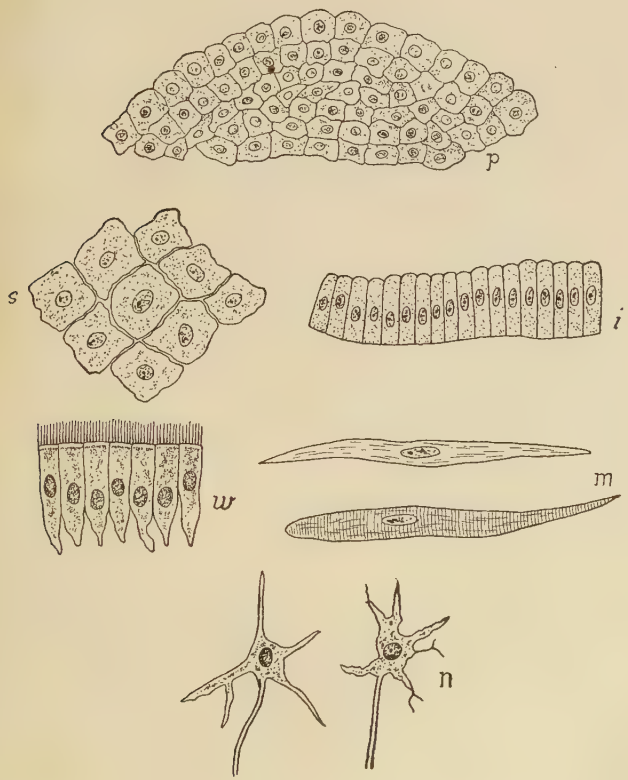

FIG. 2.—Cells of various kinds. *p*, plant cells; *s*, pavement cells; *i*, columnar cells; *w*, ciliated cells; *m*, muscle-cells; *n*, nerve-cells.

like that of a tree, a horse, or a man, the cells press against each other and are made to have

many different shapes. Also, the different kinds of cells have different kinds of work to do, and they are made so they can do their work in the best way. In Fig. 2 you can see the shapes of several kinds. The upper one shows some cells arranged in the tip of a root of a plant. *s* shows a few flat cells joined edge to edge like stones in a pavement. *i* shows a few cells standing on end like columns. The cells shown in *w* have hair-like projections on top. Two different kinds of muscle-cells are seen at *m*, and two nerve-cells at *n*. There are a number of other cells of different shape, each being adapted to the kind of work it has to do.

Single-celled animals. — There are a great number of very small animals which are composed of but a single cell. They are, in most cases, so small that they can be seen only with very strong microscopes.

A good example of this kind of an animal is shown in Fig. 3. It is called the *amœba*. It lives in the water and moist earth. If you

could see one of them it would look like a very small lump of jelly with a round dot inside. If you would continue to watch it, you would see that it is alive, for it would begin to

FIG. 3.—The amœba.

move in a very peculiar way. It has no feet, but instead it pushes out one side of its body in the direction it wishes to go and then rolls the rest of the body into it. In that way it moves along, and when it rests it is in the shape of a tiny ball.

It has no stomach or mouth, but when it meets any small particles of food it wraps its whole body around it and takes the food into its body. In that way it can make a stomach for itself whenever it needs one.

The amœba lives much as other animals do; but its life is very simple, for it has only one cell, and must use it for everything it does.

The human body made of cells.—A great number of cells just like the amœba are found in the human body. They float about in the blood and move through other parts of the body. They are called *white corpuscles*, and will be described in a later chapter.

The most of the cells of our bodies do not move about. The muscles, bones, skin, brain, liver, and so on, are all made up of many cells ; but they are fixed to one spot and their food is brought to them by the blood.

One cell cannot do very much, but when a great number of them work together to do the same thing they can do a great deal. One boy cannot pull a heavy wagon along the road, but when a number of boys all pull and push in the same direction, the wagon can be moved along rapidly.

A division of work among the cells of the body.—In a large factory of any kind the work is divided among the men who are at work there. If they are making shoes, one set of men will prepare the leather ; another will

cut it out; another will sew the pieces together, and so on till the shoe is complete. They can make shoes much better that way than if each man tried to do all the different kinds of work.

The human body is like this factory, and the different sets of men at work are like the different groups of cells in the human body.

Each group of cells has become used to one kind of work and does not try to do any other kind. The cells in the stomach look after the digestion of food. Those of the skin have nothing to do but protect the outside of the body. Those in the muscles move the body. Those in the heart keep the blood in motion. Those in the brain reach out long arms to the other cells and control their action. A great number of groups of this kind are engaged in doing a special kind of work, and each can do better work than if it tried to do many different things as the amœba has to do.

An organ.—An organ of the body is composed of a large number of cells which work

together to do a certain thing. The stomach is an organ of digestion. The lungs are the organ of breathing. The eye is the organ of sight. The ear is the organ of hearing. Whenever we use the word *organ* in this book, it will mean a collection of cells which are all working together to do some important work for the body.

The different kinds of matter in the body.—The whole body is made up of *water*, *albumin*, *fat*, *minerals*, and a little *sugar*. About three-fourths of the whole body is water. Even the cells of the hard bone and teeth are partly water.

The albumin is a very important part of all the cells. In a good-sized man there are about twenty pounds of it.

About ten pounds of a man's weight is fat, sometimes more and sometimes less than that amount.

Minerals are found in all parts of the body, but mostly in the lime in the bones. Salt is a mineral found in all the cells.

How the body is kept alive.—The body is a machine, and, like all machines, it must be kept going or it will stop. Food and air are the two things which we take into the body, and they keep the cells alive and make them able to do work.

What does the engineer do when he wants his engine to run? He shovels good coal into the fire-box under the boiler, and opens the damper so the fire can get a good draft of fresh air. The coal is the food of the engine and the draft of air is its breath. As long as the coal and air are supplied, the engine can be kept running; but as soon as either one fails, the fire will go out and the engine will stop. The engine may then be said to be dead, but a fire can be started in it at any time, and it is then alive again.

Eating and breathing are the two most important things we have to do. The food and the air do for us what the coal and air did for the engine. We have to eat about three times a day, and must breathe constantly both day and night. If we could not get food and air

the body would soon die, and, unlike the engine, life could not be started in it again.

QUESTIONS.

1. What is matter?

2. What is lifeless matter? Give some examples.

3. In what three ways does a live body differ from lifeless matter?

4. What are the two kinds of live bodies?

5. Give three important differences between animals and plants.

6. Give some good reasons for studying physiology.

7. What three things should we find out by this study?

8. What are the three parts of a cell?

9. Draw on paper or the blackboard several cells of different shape.

10. Describe the amœba. How does it walk and eat?

11. What is the human body composed of?

12. How is work divided among the workmen in a large factory?

13. How is work divided among the cells of the body?

14. What advantage is there in having different groups of cells for each special kind of work?

15. What is meant by an organ of the body?

16. What five substances are in the human body?

17. How much of the whole body is water?

18. How much of the body is albumin?

19. How does an engineer keep his engine going?

20. How do we keep the body alive and able to do work?

CHAPTER II

FOOD

What food does for the body.—Food does three things for the body. (1) It adds to the weight of the body. A growing boy or girl needs a great deal of food for this purpose. When they are full grown their weight will change very little during health. (2) The food unites with the oxygen of the air which we breathe and produces heat. A healthy body has almost exactly the same temperature all the time. (3) Food stores all the cells with material which they can use in doing work. In walking, running, and working the muscles are active and use up the material which the food brought to them.

In short, then, *warmth*, *growth*, and *ability to do work* are the three things which we get from food.

Why we have to continue to eat.—Some one might say that he eats because he

is hungry, but that would not be correct. We get hungry only when we need more food. We have to keep on eating because the food is rapidly used up and the body is constantly wearing away. Every breath which is breathed out from the lungs carries heat and water out of the body. On a cold day, even when we are well clothed, a great deal of heat gets away from the body. The body gets its heat only by burning up some of the food which we eat, and so that is one reason why we get hungry.

The greatest need we have for food is to get ability to do work.

When a man works hard he soon gets hungry, and needs to eat more than one who is idle. This is because the food which is stored in blood and in the cells of the body is rapidly used in doing work. Then the man eats again and uses that food in doing more work.

The skin is constantly wearing off and new cells from beneath form new skin.

In other ways, too, the body is constantly losing material, so that, in all these different

ways, the body of a man who is doing hard work will lose about nine pounds a day. This must be supplied by the food which the man takes into his body.

What a food is.—A food is anything that will supply what the body needs and will not do it harm. Bread, milk, meat, eggs, and many vegetables are good foods because they supply the cells of the body with what they need. Alcohol is not a food, because, even if it does make the body warmer for a time, it also injures the cells.

Difference between the food of plants and animals.—The chief difference between a plant and an animal is in the kind of food which they use.

All animals live on plants, and plants live on the food which they get from the soil and the air. All plants are at work making food for animals. If plants should cease to grow, all animals would starve for want of food. When we eat beefsteak we eat the food which

the ox got from the plants. The food in an egg was obtained by the hen from the plants. All of our food was prepared first by vegetables.

Different kinds of food.—There are three important kinds of food. They are *proteid*, *starch*, and *fat*.

The proteids are the most important of all. The larger part of a living cell is proteid, and, as it is constantly being used up, the food must bring it a new supply. The white of an egg is almost all proteid. Proteid is found only in the live cells of animals and vegetables.

Starch is also an important food which is prepared for us by the vegetables. Wheat, corn, oats, potatoes, and many other vegetables contain a large quantity of starch. The starch itself is not a food to the cells ; but the body has an easy way of changing it to sugar, as we will explain in the next chapter, and the cells then use the sugar.

The fats are obtained chiefly from fat meats, butter, milk, oils, and nuts. Fat is food which

is stored up in the body. It may not be needed just at present, but it is always ready for use. When an animal cannot get food, it will live a long time on its fat, and then it will be very lean.

There are two other substances which we must have, and they may properly be classed as foods, though they are used in a different way from the three great foods named above. These two are *minerals* and *water*.

The minerals are needed to build up the parts of the body that do not change very much. Bone is hard and strong because it contains a great deal of lime. All the material from which bone is made must come from the food which we eat.

Salt is another important mineral which is needed by all the cells. There is some salt in our food, and we add a great deal more in cooking or at the table while we are eating. Other minerals are also needed, but they are already in the other foods.

Water is not used up in the body as the proteids, starches, and fats are, but it is always

needed to dissolve the other foods and to float them out to the cells. A cell can neither work nor get its food unless it is bathed in water. The impurities which are made in the body must be washed away, and this is always done by the water. A man can live many days without the other foods, but he would hardly get through a single day without water.

Good water.—A man needs about three quarts of water every day. Part of this is taken with other foods, such as milk and vegetables; but he must drink a great deal besides.

There is little danger that any one will ever drink too much pure water. Most people drink too little. The great danger lies in drinking water that is not pure.

Water may be very clear and yet be very impure. The little germs of disease which live in water are so small that they cannot be seen with the naked eye. Water may be muddy, and yet be purer than some clear water. A filter may make the water clear, but it will not always make it pure. When water

has a foul smell it is not fit to drink; but impure water cannot always be detected by the smell of it. How then can we tell whether the water which we drink is pure or not? It is not always an easy matter. A bottle of the water may be sent to a chemist once in a while, and he can analyze it and see if it contains any impurities; but most people cannot go to that trouble and expense. The best way is to avoid water found in places where it is likely to be impure. The water in shallow wells, stagnant pools, and rivers into which the sewage of a city is emptied, is never safe to drink.

Shallow wells.—When it rains, the water either soaks into the soil or runs into the low places, forming the lakes and rivers. The part that soaks into the ground will run through cracks in the rock or through openings of any kind in the ground. In that way numerous veins of water are formed in the earth, some close to the surface and some deep in the rock. There are so many of these veins that

when we drill or dig into the earth we are almost sure to strike one of them and get a well of water. When a well is drilled deep into the rock and cased up with iron tubes, the

FIG. 4.—The kind of wells that are liable to contain impure water.

water in it is almost always pure and good to drink. This is so because the water has soaked through layers of sand, gravel, and clay, and then passed back and forth in the crevices of the rocks down to the bottom of the deep

well. This is nature's way of filtering water and making it pure.

Impure well-water is nearly always found in shallow wells. This is what we would expect. The rain-water gathers up many impurities, decaying matter, and disease germs and carries them into shallow wells. Such wells are often twenty, thirty, or forty feet deep, and are walled up with stone. Foul water can run through the wall into the well. The platform upon the well and the sod around it may be kept very neat and clean, but still the water may become very foul. Filth from a barnyard, outhouse, or sewer may be carried into such a well by a vein of water under the ground. Typhoid fever and other diseases are often caused by drinking water from such wells.

Shallow wells are always likely to contain foul water, and should be avoided if possible. Such wells in a city or town are much more dangerous than in the country.

City water.—Many cities and towns are supplied with good water from wells and

springs or lakes. Such water is often brought from a long distance and pumped through pipes into the city. One of the most important things a city or town has to do is to supply its people with good drinking-water. City water sometimes also becomes impure and many people become sick, for everybody must drink water. When it is suspected that water contains germs which cause disease the only safe course is to first boil the water for twenty minutes or more. This will kill all living germs.

Freezing the water will not purify it. It is a bad practice to put broken ice into the drinking-water. The ice may be impure, and it makes the water too cold for a healthful drink.

Some good foods.—Wheat is one of our best foods because it contains all the different kinds of foods we have named. It is rich in proteid and starch, and also contains some sugar and fat. Dough made of flour is sticky because of the gluten in it, and gluten is chiefly

a proteid food. When yeast is mixed with it, the whole lump of dough will "rise." This is caused by millions of little yeast-plants which grow rapidly in dough. They set free a great number of bubbles of gas called carbon dioxide. The sticky gluten holds the bubbles in the dough, and as the amount of gas increases the dough is forced to "rise." When the dough is placed in a hot oven it will rise rapidly, because the heat makes the gas expand. Baked bread will contain numerous holes where the gas was formed.

One can live very well on good bread and butter alone.

Corn is rich in starch and fats, but has only about one-half as much proteid as wheat has. That is why corn bread will not rise as well as wheat bread. Corn bread is a wholesome food.

Peas, beans, potatoes, and many fresh vegetables are also desirable foods when mixed with other foods.

Meats and eggs are rich in proteid and fat. They are valuable foods for men who do hard

work, but not so good for boys and girls or for those who sit at their work all day. Meats should always be well cooked. Beefsteak is much better than pork.

Good milk is a perfect food for children, but it alone is not enough for people who are grown.

The need of a mixed diet.—While bread contains all the different kinds of foods, it is not best to eat bread alone. We would have to eat too much starch to get the right amount of proteid. It is better to eat some good meat or egg with the bread. In that way we can get just the right amount of each kind. Fresh vegetables and fruits are also necessary to a good diet.

Amount of food.—While there are some who do not have enough to eat, yet probably more sickness and disease are caused by eating too much rather than by eating too little. One should quit eating as soon as he begins to feel satisfied. It does not require much

good food to keep the body strong and in good health. Too much food only creates poisons in the body.

Cooking.—Most foods should be cooked. The starch in wheat, rice, corn, potatoes, and other foods are much more easily digested when cooked. All food must be in a liquid form before it can get into the blood, and starch is easily dissolved when it is cooked.

Meats should be cooked to make them tender. They can then be finely ground between the teeth and will more rapidly dissolve in the stomach.

Cooking also makes the meats taste better, and if it should be diseased, as often happens in pork, the heat of cooking will prevent any harmful effect. Pork should always be cooked through and through.

Good cooking is as necessary to good health as good food.

A good cook in a family is of greater service than a doctor.

There are many excellent cook-books from

which any girl who desires may learn to be a good cook.

Alcohol as a food.—Some people drink beer, whiskey, and other drinks that contain alcohol. They say that it keeps them warm in winter-time and makes them strong and healthy. This is a great mistake, as we will show in several places in this book. Alcohol is a poison to the cells of the body. It will make the body warmer for a while, but it also causes the body to lose much more heat than it gains from the alcohol, as will be shown in the chapter on the circulation of the blood.

There is nothing in alcohol to build up the body. The only way it could be a food would be in making heat, and in that it does more harm than good.

Some people think certain kinds of alcoholic drinks, such as beer, are good food because they make people fat. But fat people often have very poor health and can do very little work. Beer will make people fat, but it at

the same time will make them unhealthy. It makes fat cells take the place of cells in the muscle, liver, kidney, and so on. In that way those organs are made weaker instead of stronger. Fat cells are of no use in the operation of the body. Beer, then, cannot be a food, because it destroys good cells and puts poor ones in their place.

The worst results from the use of alcohol are its poisonous effects on the cells. A little alcohol may seem to do no harm, and the body can recover from its effects as it does from sickness. But any alcohol in a healthy body will do harm. Continued drinking of beer, whiskey, brandy, hard cider, and other such drinks is sure to result in a weakened condition of some of the important organs of the body.

A food will supply what the body needs, without doing harm, and so alcohol cannot be classed as a food.

A healthy appetite will call for the proper kind of foods, and it never calls for alcohol.

An appetite for strong drink is always

caused by a diseased condition of the body brought on by the alcohol itself.

QUESTIONS.

1. What are three uses of food?
2. Why do we need to eat?
3. What becomes of the food?
4. Define a food.
5. How do we know that bread is a good food?
6. How does our food differ from that of plants?
7. Name three kinds of food.
8. What is proteid?
9. Whence do we get the starches?
10. What is the use of fat?
11. Name two other substances that may be classed as foods.
12. What is the use of the minerals?
13. Why is water necessary?
14. Where can good water be found? Why?
15. Explain why the water in a shallow well is liable to be impure.
16. How are cities supplied with water?
17. What is the source of water that *you* drink?
18. Why is wheat a good food?
19. What causes bread to rise?
20. Is meat a good food?
21. Why not eat only bread?

22. How much should one eat?
23. Why should starch be cooked?
24. Give some reasons for cooking meat.
25. How can one learn to cook well?
26. Does alcohol make the body warm?
27. Does alcohol make the body fat? How?
28. Is alcohol a food? Why not?

CHAPTER III

DIGESTION

The use of digestion.—The organs of digestion, all taken together, form a long tube of uneven size. At some places the tube is small and at other places it swells out into a pouch like the stomach. This tube is a passage-way for the food from the mouth clear through the body.

While food is in the tube it is still on the *outside* of the body. Food is not properly *in* the body until it is in the blood. It must get through the walls of the tube to the numerous small blood-vessels on the other side. This cannot be done until the food is first changed to a liquid form. Much of it must also be changed into other kinds of substances. Starch, for example, must all be changed to sugar, and the sugar is then easily dissolved. Then it is carried through the walls of the tube and joins the current of blood.

The organs of digestion.—Most of the food must pass through several changes before it is fully digested. These changes are made at different points along the tube. One kind in the mouth, another kind in the stomach, still another in the intestines, and so on. So we will describe several different organs of digestion in order,—the *mouth*, *pharynx*, *œsophagus*, *stomach*, *small intestines*, and *large intestines*.

Mucous membrane.—The whole digestive tube is lined with *mucous membrane*. This is, in fact, a kind of skin which lines all cavities in the body that open in any way to the outside. It can be seen in the mouth and nostrils. It lines the whole mouth and extends on down along the gullet and covers the inside of the stomach. Extending on, it lines the whole intestines. At the lips it can be seen how the hard outer skin joins to the soft mucous membrane.

The mucous membrane is very important in digestion. It is made of cells which have different shapes in different places. Some of

these cells pour out onto the surface of the membrane a sticky fluid called *mucus*. This is what makes the saliva "ropy." Other cells are busy collecting juices of one kind or another and pouring them upon the food as it passes along.

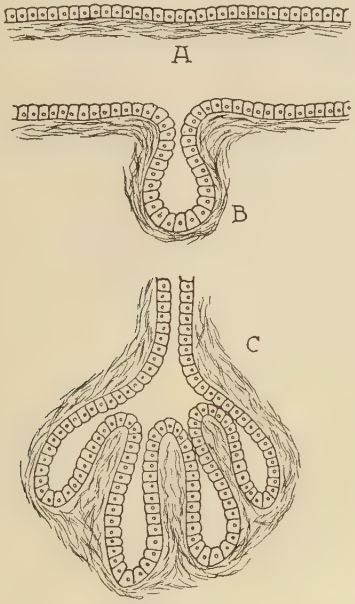

FIG. 5.—Glands. *A*, mucous membrane; *B*, fold forming gland; *C*, compound gland.

A gland.—The mucous membrane in places will fold in and line a pocket as shown

in B, Fig. 5. The cells in such a pocket, or pouch, undertake a special duty of collecting liquids from the blood and making them over so that they can do some special work. For example, several groups of cells arranged in this way will produce saliva and pour it into the mouth. Others will produce gastric juice and pour it into the stomach. Other juices used in digestion are produced in a similar way. Such a group of cells is called a *gland*. Often a number of these pockets are joined together in one gland as shown in Fig. 5, C. The liquid gathered by the gland is poured out through a tube called a *duct*.

Digestion in the mouth.—The first work of digestion is accomplished in the mouth. Here two things should take place. (1) The food should be ground into very fine pieces by the teeth. (2) It should be thoroughly mixed with saliva. Both are important operations in digestion.

Teeth.—The teeth begin to cut through the gums when a child is only about six

months old. They keep coming, one after another, until he is about two years old. Then he has ten teeth in each jaw. These are only *temporary* teeth. They do not last

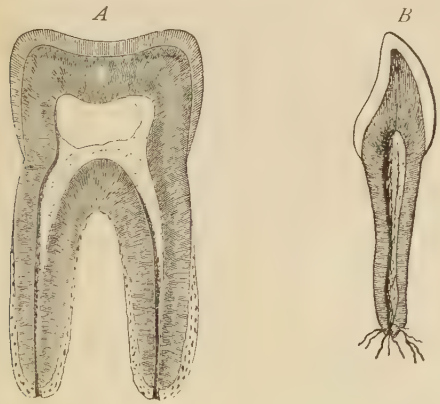

FIG. 6.—Section of teeth. *A*, molar; *B*, incisor.

long. At the age of five or six years another set begins to grow just beneath the temporary ones. The new teeth gradually push the old ones out. At the age of twelve or thirteen the new set, called the *permanent* teeth, have all appeared. Of these there are fourteen in each jaw. At the age of twenty or twenty-five years the "wisdom teeth" appear, making the full set of sixteen in each jaw.

Kinds of teeth.—There are four kinds of teeth in each jaw. (1) The *incisors* (the cutters). There are four of these in each jaw in front. They have a sharp edge and are fitted to bite off morsels of food. (2) The *canines* (dog teeth). There are two of these in each jaw, one on each side just back of the incisors. (3) Biscupids (two cusps), two on each side, just back of the canines. (4) Molars (grinders), the three large back teeth on each side.

The structure of teeth.—The part of a tooth which extends beyond the gum is called the *crown*. The part fastened into the bone of the jaw is the *root*. The front teeth have but one root, and the back ones have three or four. All are firmly fixed into the bone with cement.

The crown is covered with a very hard substance called *enamel*. Enamel is the hardest substance in the body. It needs to be hard, so that the teeth will not be worn away by the constant biting and grinding which they have to do.

On the inside of a tooth is a cavity which is filled with a soft substance called *pulp*. In the pulp are numerous small blood-vessels and nerves. Around the pulp is a hard bony material called *dentine*, and outside of all is the enamel. The blood-vessels bring the needed food to the cells in the hard substance of the tooth, and the nerves notify the mind whenever anything goes wrong in the tooth. Teeth will easily decay when they do not receive proper care.

Use of teeth.—Good teeth that are kept in good condition will add a great deal to one's personal appearance, but their chief use is to grind the food. This grinding is the first act of digestion, and it is an important one.

When you wish anything to dissolve rapidly in water you first pound it into a fine powder and then stir it into the water. In the same way the food must be ground into fine bits so that it can be easily and rapidly dissolved by the digestive juices.

Saliva.—Saliva is a thin watery fluid which is collected by six glands located about the lower jaw. One gland is located just below and in front of each ear, and the other four are beneath the tongue. They are known as the salivary glands. They are composed of a great many sacs, or pockets, all joined together so that the whole has the appearance of a bunch of grapes, as shown in Fig. 7.

FIG. 7.—A racemose gland.

Just outside the pockets of the gland are numerous fine blood-vessels. As the blood passes along, the cells in the gland take up the liquid which they make into saliva.

Use of saliva.—While the food is being ground by the teeth, the salivary glands are busy making saliva and pouring it into the mouth through their ducts. The saliva has two important uses. (1) It moistens the food so that it can be ground still finer by the teeth and can be easily swallowed. Dry food

would stick in the throat. (2) It dissolves part of the food. Such substances as candy, sugar, and salt are dissolved in the mouth by the saliva. There is also in saliva a ferment which changes some of the starch into sugar, and the sugar is then dissolved. Not much of the starch is changed to sugar in the mouth; but after the food is swallowed and gets down into the intestines, the ferment of the saliva continues to change starch to sugar.

It is important that food be finely ground and well mixed with saliva before it is swallowed.

Experiment 1.—Cook a little starch and make of it a thin paste. Fill a small bottle or test-tube about half full of the starch paste and add to it a little saliva, about a tablespoonful. Shake the bottle and keep it at about the temperature of the blood in the body, 98° Fah. The starch paste had a cloudy appearance, but after the saliva was added it soon cleared up. The starch was changed to sugar and then dissolved in the water of

the mixture. The liquid now has a sweet taste.

Experiment 2.—Put into a glass of water some chunks of hard candy. Into another glass, containing the same amount of water, put the same amount of candy, but first pound it till it is broken into fine grains. Stir the liquid in both glasses, and notice how much sooner the candy in the second glass will dissolve. The same can be done with ice or rock-salt.

This will illustrate the advantage of chewing the food into fine bits.

The pharynx.—Just back of the mouth is an irregular cavity, or box, called the *pharynx*. The pharynx has seven openings. Two at the top lead into the nostrils. One at each side opens to the ears. One in the bottom leads to the stomach and another to the lungs. In the front, the pharynx opens into the mouth.

After the food has been chewed and mixed with the saliva, it is pushed by the tongue into the pharynx. Then all the openings are

closed except the one which leads to the stomach, and the food is thus started down the tube called the œsophagus. Close by the œsophagus is the windpipe, but there is a lid on the top of the windpipe and it closes down whenever we swallow. The food then slides over the top of this lid to the opening of the œsophagus which is just behind. Sometimes particles of food get under the lid and into the windpipe, causing violent coughing.

The two parts of the trunk of the body.—Before we describe digestion further, we should here learn that the trunk of the body is divided into two parts by a partition called the *diaphragm*. The diaphragm stretches clear across the cavity of the trunk and is fastened to the walls of the trunk near the lowest pair of ribs.

The part of the trunk above the diaphragm is called the *chest* or *thorax*. The thorax contains the heart, lungs, and large blood-vessels.

The part below the diaphragm is called the *abdomen*. It contains the stomach, intestines,

liver, kidneys, spleen, pancreas, and many small blood-vessels.

The œsophagus.—The œsophagus is a tube which runs from the pharynx down

Fig. 8.—Œsophagus.

through the thorax and through the diaphragm into the stomach. All digestion is done in the mouth and in the abdomen. Food passes rapidly from the mouth to the stomach.

One layer of muscle in the wall of the œsophagus runs around the tube. When a

lump of food enters the top of the tube, a ring of muscle will contract just above it and make the tube smaller on that side. In that way the food is pushed down a little way. Then other rings contract in the same way and push the lump of food farther and farther until it reaches the stomach.

It is not possible to swallow unless there is something in the œsophagus. When food is once started down the œsophagus, it will be carried on to the stomach without any further attention.

Experiment 3.—Swallow two or three times to remove the saliva from the mouth. Then try to swallow again. You probably will not succeed. If you do, try two or three more times rapidly, and you will find at last that, however hard you may try, you cannot perform the act of swallowing. This is because there is nothing to swallow.

Experiment 4.—Secure a piece of soft rubber tubing and fill it with putty or soft

clay. Hold it as shown in Fig. 8 and close one finger after another against the tube. By

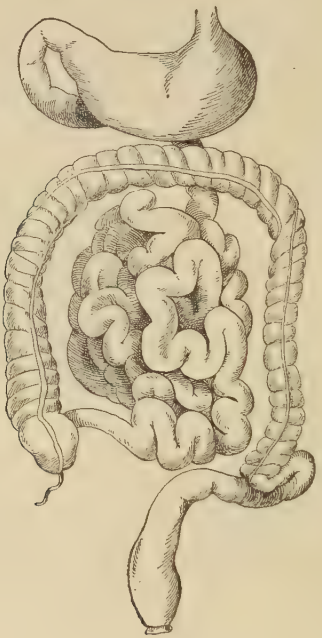

FIG. 9.—Stomach and intestines.

doing so the putty will be pushed out at the lower end of the tube. This illustrates how the œsophagus pushes the food down to the stomach.

The stomach.—We have said that the food is all digested in a long tube which runs

from the mouth through the body. We have now traced some food from the mouth to the pharynx, and then into the œsophagus, which carried it down through the thorax and diaphragm. We have now come to a place where the tube widens out into a large pouch called the stomach.

The stomach is placed in the upper part of the abdomen and on the left side. It presses against the lower side of the diaphragm. The food enters the stomach at the *cardiac orifice* and leaves it at the *pyloric orifice*. (See Fig. 9.)

The mucous membrane which lines the stomach contains numerous small glands. These produce *gastric juice* and pour it out freely onto the food in the stomach. The gastric juice contains acid and is quite sour. It rapidly dissolves all proteid foods. That is, substances like white of egg, meat, gluten of bread, and so on. It does not change the starch or the fat.

A layer of muscle in the walls of the stomach will contract on one side, and then on the

other, thus keeping the food in motion and mixing it with the gastric juice.

All the proteids, fats, starches, and other foods are mixed together, making a mass something like thick cream. This mass is called *chyme*.

In a short time after a meal, some of the food has been digested. The pyloric orifice opens and lets this part out. Little by little the chyme flows out, and in from two to four hours the stomach should be empty again.

Experiment 5.—Secure at a drug-store a small bottle of pepsin in a solid form. Put about one teaspoonful of it into a half-teacup of warm water. Stir till it dissolves. Add four or five drops of hydrochloric acid. This will be a gastric juice.

Thoroughly mince a very little of the white of a hard-boiled egg and place it in the cup. Keep it warm, about 98° Fah. In an hour or less the egg will be dissolved. The action is better observed if a bottle or test-tube is used instead of the cup.

This will illustrate the kind of digestion which takes place in the stomach.

The small intestine.—When the chyme leaves the stomach it enters the *small intestine.*

FIG. 10.—Section of small intestine.

This is a tube about twenty feet in length. It begins at the stomach and is folded from side to side in the lower part of the abdomen, and finally opens into the large intestine.

As soon as the chyme from the stomach enters the small intestine, it is mixed with two fresh juices which were prepared for its coming. These are the *pancreatic juice* and the

bile. The work of digestion was begun in the mouth and continued in the stomach, and these new juices now complete the digestion.

Pancreatic juice.—The *pancreatic juice* rapidly changes all starch to sugar, and changes the fats so they can get through the mucous coat of the intestines.

This juice is collected by a racemose gland called the *pancreas*. The pancreas is a slender body about eight inches long, and lies just back of the stomach. The special work of its cells is to produce pancreatic juice whenever it is needed, and pour it out through a duct onto the food in the intestines.

The bile.—The liver is a large and very important gland, which will be described a little farther on in this book. It has many duties to perform, and one of them is to collect *bile*, which is poured onto the food along with the pancreatic juice.

Bile is a yellowish fluid, which is collected in the *gall-bladder* under the liver and emptied onto the food when needed.

It gives valuable help to the pancreatic juice in completing the process of digestion.

The chyle.—After the food is fully digested in the small intestine it is called *chyle*. Chyle is a thin white liquid. The fat is not dissolved, but only broken up into very fine droplets, and they make the chyle look white.

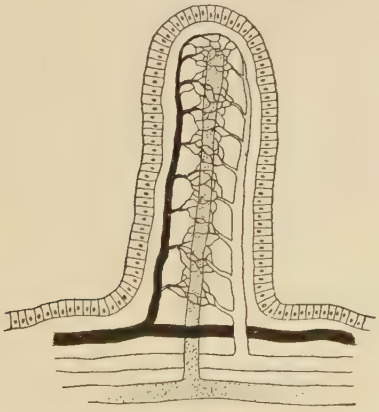

FIG. 11.—Villus.

The food is now all digested and ready to enter the blood; but how does it get to the blood-vessels?

The villi.—The inner surface of the small intestine is thickly covered with small projec-

tions which look a little like the nap on a piece of velvet. These are the *villi*, which dip into the liquid food. In Fig. 10 is a section across the small intestine of a cat. The section is very thin, and so the villi do not seem to be crowded, but they stand close together all over the surface.

When a single villus is closely examined with a microscope, it is seen to be covered with a layer of cells, as shown in Fig. 11. On the inside are numerous fine tubes, which run in every direction and are connected together so as to form a fine net-work. These are blood-tubes, and because they are so small they are called *capillaries*. Another tube of a little different kind runs up through the villus. It is called a *lacteal*, because after digestion it is filled with a milky-white liquid.

How the food gets into the blood.—We see, then, that there is only a very thin layer of cells between the food in the intestines and the tubes in the villi. The blood is flowing through the capillaries in the villi all the time,

whether there is any food to be taken up or not. But when there is rich food in the intestine, and the blood needs it, some is sure to soak through the layer of cells and join the

FIG. 12.—Apparatus to illustrate the passage of liquids through a membrane.

stream of blood as it flows along. The albumin, and sugar, and water, and minerals go into the blood capillaries, but the fine globules of fat go into the lacteals. That is what makes the lacteals white.

Experiment 6.—Strip some of the outer membrane from a large piece of bologna and tie it tightly over the bottom of a lamp chimney. Fill the chimney to a depth of an inch or two with a solution of strong salt water, and support the chimney so that the bottom dips into fresh water, which is slightly colored with some aniline dye. In an hour or more the fresh water will have a salty taste, and some of it, as shown by the color, will have passed up into the chimney. This shows how liquid foods may easily pass through a similar membrane to the capillaries.

QUESTIONS.

1. When is food properly in the body?
2. Why is digestion necessary?
3. Name the parts of the tube through which the food passes during digestion.
4. Describe the mucous membrane.
5. What is a gland, and how are they formed?
6. What is the duct of a gland?
7. What are the first two acts of digestion?
8. Describe the temporary set of teeth.
9. Describe the permanent set of teeth.

10. Name and locate the different kinds of teeth.

11. What is enamel?

12. What is on the inside of a tooth?

13. What important work of digestion do the teeth have to perform?

14. How is saliva made?

15. What are two uses of saliva?

16. Describe and perform an experiment showing how saliva acts on starch.

17. Describe an experiment showing that food should be broken into fine bits. Perform the experiment.

18. Where is the pharynx?

19. What are the seven openings from the pharynx?

20. How does food get across the top of the windpipe without falling in?

21. What is the diaphragm? Where is it?

22. What organs are in the thorax?

23. What organs are in the abdomen?

24. Where is the œsophagus?

25. How does the œsophagus push the food down to the stomach?

26. Describe and perform an experiment showing how the œsophagus works.

27. Where is the stomach?

28. What are the two openings of the stomach?

29. How is gastric juice made?

30. What kind of food will gastric juice digest?

31. What is chyme?

32. How long does food remain in the stomach?

33. What kind of food will pancreatic juice digest?

34. How is pancreatic juice made?

35. How is bile made?

36. Describe the small intestines.

37. What is chyle?

38. What is the use of the villi?

39. Describe a villus.

40. How does the food get from the intestines into the blood?

CHAPTER IV

CARE OF THE DIGESTIVE ORGANS

Advantage of healthy organs of digestion.—All of our strength comes from the food which we eat. We have to eat every day to get ability to work. This is true not only of work which we do with our muscles, but we cannot think well unless we eat and digest good food.

The only natural way by which food can get into the blood is through the organs of digestion. It is very necessary that these organs be kept in a healthy condition, for we must rely upon them for our supply of food.

An unhealthy condition of the stomach or intestines not only makes a man very miserable, but also weakens all the other parts of the body by cutting off their supply of food.

A healthy stomach is a great blessing. With proper care it will always do its work

very faithfully, but it may easily be disordered by improper usage.

Dyspepsia is a common disorder of the stomach, which is usually caused by bad foods and improper eating.

The best time to take good care of the stomach is while it is in a healthy condition.

Chewing the food.—It is important that the food be thoroughly chewed before it is swallowed. Good cooking and proper preparation of foods are a great help in digestion; but still the food should be kept in the mouth long enough to grind it very finely and mix it with saliva. It is a bad habit to take water or other drinks into the mouth to hurry dry food down the throat. Bread and other dry food should be moistened in the mouth only by saliva.

Care of the teeth.—It will not be possible to grind the food thoroughly unless there is a good set of molars. The permanent set of

teeth may be kept sound for a long time, but without proper care they will soon decay.

Decay begins in a small spot on a tooth, and, if allowed to continue, will widen and deepen till it reaches the pulp and produces a violent ache.

Teeth should be examined by a dentist once or twice a year, and any decay can thus be checked at the beginning and the tooth can be saved.

Teeth should always be cleansed after eating. Decay may be started by small particles of food which become wedged in between the teeth. These particles should be removed after each meal by use of a soft wooden toothpick, and the teeth should be brushed with some good tooth-wash or some mild soap.

Teeth that are neglected often become covered with a coating called *tartar*. This makes the teeth yellow and gives the whole mouth a repulsive appearance. It can be removed by a dentist, and the teeth may afterwards be kept clean and white by frequent washing with a stiff brush.

When decayed teeth cannot be repaired, they should at once be removed from the mouth.

Care of the stomach.—If the stomach is kept in a healthy condition, all the other organs of digestion will be cared for at the same time. But when the stomach fails to do its work, the whole body suffers at once.

Nearly all the ills of the stomach result from improper methods of eating, poor food, good food poorly prepared, and taking injurious substances which are not foods into the stomach.

Eating too much or too often is a common evil. The stomach, like other organs, needs periods of rest. The best cure for indigestion is, often, to eat nothing for a time.

Eating too rapidly will throw work onto the stomach because the food will not be finely chewed, and so must remain a longer time in the gastric juice before it will be dissolved.

Food that is not properly cooked is often a cause of much of the trouble in digestion.

There is a way of preparing even the simple foods, such as bread, potatoes, and meats, so that they not only taste much better, but can be more thoroughly digested.

Mental condition has much to do with digestion and a healthy stomach.

A gloomy state of mind has a depressing effect on every organ of the body. A cheerful and happy state of mind will assist digestion. The conversation at the table should be, if possible, only on pleasing topics, and all worry should be cast aside.

A short period of rest and relaxation before and after meals is a great aid to digestion. This is true of both mental and physical labor. Any part of the body that is being hard worked will take a larger amount of attention and blood than usual. For this reason, hard study or intense physical exercise will, to some extent, decrease the activity of the digestive organs.

Effect of alcohol on the organs of digestion.—Alcohol hinders digestion and

produces a diseased condition of the digestive organs.

It was once quite common to have wines, beer, whiskey, or other alcoholic drinks served at meals. It was believed that they were a food, and also that they helped to digest other foods. Careful study has shown that this is a grave mistake, and those who care for their health no longer use alcoholic drinks in this way.

Alcohol makes food less digestible. Proteid, in particular, is hardened and shrivelled by alcohol, and must remain longer in the stomach before it is digested.

If alcohol acted only on the food, its bad effect would not be so great. But it injures the linings of the stomach itself.

Most drinkers are troubled with catarrh of the stomach. The delicate mucous membrane becomes inflamed and sore. The gastric glands are thus weakened and diseased. They cannot produce gastric juice of the right quantity or quality.

Thus alcohol makes the food less digestible,

and at the same time weakens the organs of digestion.

When the stomach is not healthy, it causes a great deal of suffering and misery. If, at such times, a drink containing a large amount of alcohol be taken, the pain may, for a time, cease. The drinker is often deceived by this, and thinks the alcohol is making him well because it stopped the pain. The truth is that the alcohol only made the trouble still worse; but it did benumb the ends of the nerves so that there was no pain for a while. As soon as the effect of the alcohol is gone, the pain is likely to be greater than before.

Moderate drinking.—When alcohol is taken in large amounts, its poisonous effect can be very plainly seen. But when it is drunk in small amounts, and only now and then, it may appear to have no bad effect. The body is able to recover from the injury done by the alcohol when the amount is small. This is true of any poison. A few very small doses of arsenic may be thrown off by the

body, and none of the cells may suffer any particular injury, though arsenic is a strong poison.

Alcohol is also a poison to the cells of the body, no matter whether the amount is large or small. The reason a small amount does not at once plainly poison the body is because the body is strong enough to fight it off or to recover from slight injuries.

Bread, meat, and other foods will supply the cells with what they need, but alcohol always tends to do them harm.

Appetite for strong drink.—Nearly all drunkards began by drinking just a little now and then. A little is enough to start an appetite for more. The appetite grows until only a large quantity will satisfy it.

An appetite is a good thing. It is the body's way of telling us what kind of food it wants. When the body is perfectly healthy, it is safe to eat and drink whatever the appetite calls for. But not many people have an appetite that they can safely follow. Some are born

with appetites that will lead them to take harmful substances into the body.

It is easy to cultivate an appetite for things that will injure the body, and that is why it is not often a safe guide.

An appetite is easily created for alcohol, tobacco, opium, and a number of drugs. Each time it is satisfied it grows stronger, and after a while it cannot be refused.

This is another reason why moderate drinking is a bad practice, for, little by little, it creates an appetite for more. In this way many have become drunkards.

Amount of alcohol in some common drinks.—The common drinks that contain alcohol are *malt liquors*, *wine*, and *strong drinks*.

Malt liquors are such as beer and ale. The strongest of them do not contain more than one-tenth alcohol. These liquors are made from grain.

Light wines, also, are about one-tenth alcohol, but a great deal of alcohol is often

added to wines. Sometimes one-third of the wine is alcohol.

Strong drinks are those that contain a large amount of alcohol. They are such as whiskey, rum, and brandy, all of which are about one-half alcohol.

Patent medicines.—Some of the patent medicines contain more alcohol than is ever found in beer or wine. These medicines are sold at every drug-store and are widely advertised as cures for a great many ills. Some of the most widely known of these medicines are from one-fifth to nearly one-half alcohol. The bitters which are offered as cures for stomach trouble contain a large quantity of alcohol, and give relief of the same kind that a glass of whiskey gives.

Tobacco and digestion.—Tobacco contains a substance called *nicotine*, which in a pure state is very poisonous. Those who use tobacco are almost sure to get some of this poison into the stomach. When one is

not used to tobacco, it will make him very sick. This shows that it is something which does harm, or the organs of digestion would not rebel against it. A full-grown man whose body has become used to tobacco may not appear to be harmed by smoking a cigar once in a while, but the effect of tobacco, like alcohol, is always something from which the body has to recover.

The constant use of tobacco has a bad effect on the mucous membrane of the mouth and throat and stomach.

The sense of taste becomes dull, and the appetite is often destroyed.

Those who are still growing are always harmed by the use of tobacco in any form.

QUESTIONS.

1. Give some advantages of a healthy stomach.
2. What is dyspepsia? (See dictionary.)
3. Why should water not be taken into the mouth with the food?
4. Give several rules for the care of the teeth.
5. What is the effect of eating too much?
6. How will eating too rapidly injure the stomach?

7. How can cooking assist the stomach?

8. How does worry affect digestion?

9. Why should one have rest before and after meals?

10. What effect does alcohol have on the stomach?

11. Why does alcohol seem to help a disordered stomach?

12. Does a little alcohol do harm?

13. What is the use of appetite?

14. How may an appetite be spoiled?

15. Name several drinks and tell how much alcohol they contain.

16. What are malt liquors? (See dictionary).

17. How much alcohol in patent medicines?

18. What are some of the bad effects of tobacco?

CHAPTER V

CIRCULATION OF BLOOD

Why the blood must circulate.—The blood receives all the food and every cell of the body needs food. But the cells are nearly all fixed in one place and cannot go after their food, so it must be brought to them. The muscles in the arm, for example, would soon become weak and helpless if fresh food were not constantly brought to them in the stream of blood. The cells in the brain would at once cease their action if the supply of blood were shut off. We would not be able to think, unless the brain-cells get a constant supply of blood.

When a cell uses its food, it always produces some waste matter that must be carried away. The circulating blood does this also.

Circulation, then, does two important things for the body: (1) It carries food to the cells. (2) It carries waste matter away from them.

How the stream of blood gets a fresh supply of food.—The stream of blood is forced by the heart to go around and around through every part of the body. At one place in its circuit it comes very close to the food in the intestines. Here is where the blood takes up a fresh supply of food.

The blood may be compared to a delivery-wagon which makes a circuit through a city and delivers groceries from house to house. Each time the wagon completes a circuit it is again loaded at the grocery and proceeds with its work of distribution.

The blood flows slowly through the fine tubes in the villi of the intestines at all times, and some food is taken into it at all times, but most rapidly just after the digestion of a hearty meal.

All the food, except the fats, as soon as it gets into the current of blood, is carried straight to the liver.

The liver.—The liver is one of the organs of digestion because it makes the bile which

is needed in digestion. But it has other work to do which is more important than making bile.

The liver is a gland. It is the largest gland in the body. It is placed on the right side

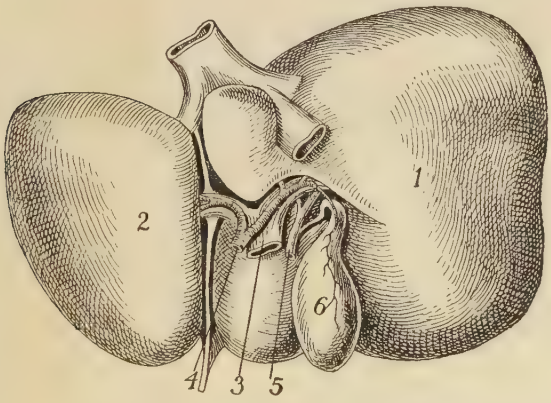

FIG. 13.—The liver. 1, right lobe; 2, left lobe; 3, portal vein; 4, artery; 5, bile duct; 6, gall-bladder.

of the body just below the diaphragm, and weighs from three to four pounds. It is made up of a great number of liver-cells, and between the cells are thousands of fine tubes, which carry blood through the liver close to the cells. These cells make important changes in the blood while it flows by them.

The use of the liver.—All the blood that circulates through the walls of the stomach and intestines, where the new food is taken up, is next carried to the liver. The liquid food is not ready to go to the heart until it is first acted on by the liver.

The sugar that was eaten, and the starch that was turned to sugar, are stored up in the liver. In that way this large gland acts as a storehouse for the body, and deals out food little by little as we need it. If it were not for this work of the liver, we would have to eat a little nearly all the time, just as we now have to breathe all the time because we have no storehouse for air.

The liver also takes out of the blood many things which would harm or poison the cells if allowed to circulate through the body. In that way the liver is always on guard and always trying to keep the blood pure.

The liver, then, does three things: (1) It makes bile for use in digestion. (2) It acts as a storehouse of food. (3) It purifies the blood.

After the food passed through the liver it was carried by a large vein up to the heart.

The thoracic duct.—Nearly all the food that was taken up from the intestines was carried by blood-vessels straight to the liver. But most of the fat did not go that way. We saw in Fig. 11 that each villus contains, besides the fine blood-vessels, another tube called a lacteal. These tubes gather up the fat and carry it to the *thoracic duct.* The thoracic duct is a tube which runs along the spinal column and joins a large vein in the left shoulder. In this way the fats are also carried to the heart.

The course of the blood.—The blood is forced by the heart to go out through tubes that run to every part of the body and then return to the heart again. These tubes are all closed so that the blood cannot get out, except as some parts of it may soak through to the cells. The organs that make the blood circulate and carry it through the body are the *heart*, *arteries*, *capillaries*, and *veins*.

The heart.—The heart is the chief organ of circulation. The blood would soon cease to flow if the heart would quit beating. The

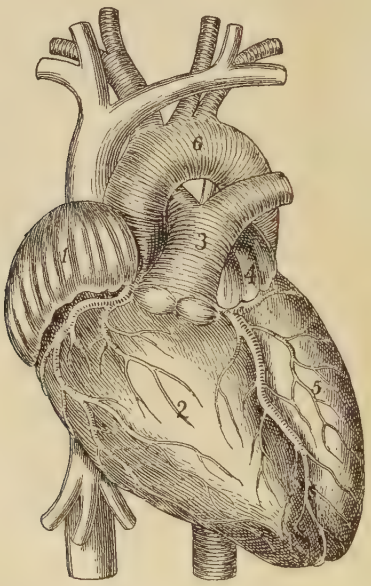

FIG. 14.—Human heart. 1, right auricle; 2, right ventricle; 3, pulmonary artery; 4, left auricle; 5, left ventricle; 6, aorta.

heart is just above the diaphragm at about the centre of the chest. It is a hollow bundle of muscle in the shape of a pear. Its large end

is towards the right shoulder, and the small end points forward and to the left.

The heart is enclosed in a bag called the *pericardium*. This bag is lined with a very smooth membrane, which is always moist. When the heart beats, there is almost no friction between it and the pericardium.

The heart is double.—Every heart is double. There are two separate hearts joined together as one. They are called the *right heart* and the *left heart*. The right heart receives all the blood as it returns from its journey through the body and sends it to the lungs. The left heart receives the blood when it comes back from the lungs and sends it out through all parts of the body. The left heart has much the harder work to do, and so it is stronger.

The cavities of the heart.—Each side of the heart contains two cavities. The upper ones are called *auricles* and the lower ones *ventricles*. So there is a *right auricle* and a

right ventricle, and a *left auricle* and a *left ventricle*. These parts are shown in Fig. 15. Each auricle is separated from its ventricle by a valve.

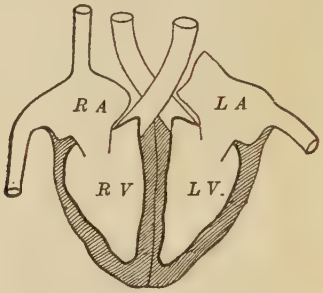

FIG. 15.—Four cavities of the heart. *R A*, right auricle; *R V*, right ventricle; *L A*, left auricle; *L V*, left ventricle.

How valves work.—Valves are in common use in pumps and in many machines

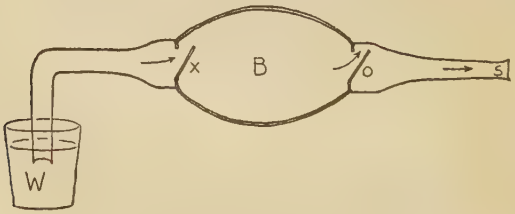

FIG. 16.—The action of valves.

which we use every day. By the use of two valves, a liquid can be made to flow always in

the same direction. In Fig. 16, B is a strong rubber bulb ; *o* and *x* are valves. If B is now filled with water and then squeezed with the hand, the water will start to flow out at both ends. But this will close *x* and open *o*, and all the water will flow towards *s*. If the hand be now opened, the walls of the bulb will spring back and start to draw water in at both ends. But this will close *o* and open *x*. The water will then be drawn only from W. If the bulb be now squeezed again, this water, also, will be sent towards *s*.

Valves of the heart.—The valves in the heart are arranged in about the way we have just described. The blood flows into the heart, and then the strong muscular walls squeeze upon it and force it out. But this would be of no use if the blood could flow back through the same tubes by which it entered ; so each side of the heart is provided with two valves. The right heart has two and the left two. These valves are shown in Fig. 17. The blood enters first

into the right auricle, *D*, and flows through the valve, *e*, called the *mitral valve*. This valve opens only towards the right ventricle. When the muscles of the right ventricle contract, the

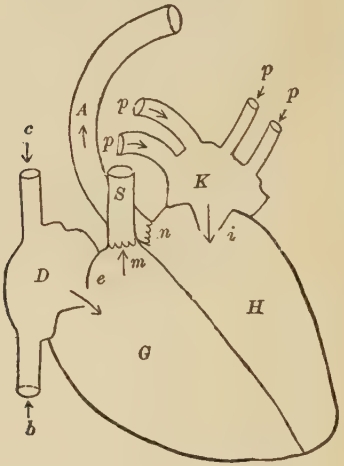

FIG. 17.—Valves of the heart.

valve, *e*, will be pushed shut, and the blood can get out only through the valve, *m*, called the *semilunar valves*, which open only outward. In that way the blood is pushed through the tube, *S*, which carries the blood on to the lungs.

When the blood returns from the lungs it enters the left auricle, *K*, and passes on

through the valve, *i*, called the *tricuspid valve*, into the left ventricle, *H*. When the left ventricle squeezes upon the blood, the valve, *i*, is pushed shut and *n* opens. Thus the blood is forced out through *A* and carried all through the body.

Arteries.—Arteries are tubes which carry blood that is sent out from the heart. They

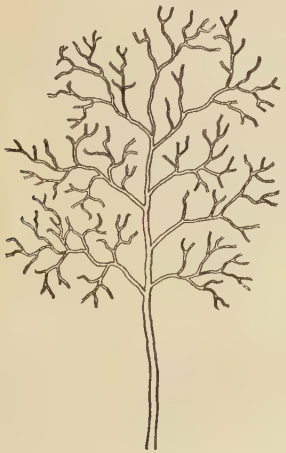

FIG. 18.—Branching of an artery.

are elastic, like a rubber tube, and always stand open whether there is any blood in them or not.

One large artery leads *out* from each ventricle. The one from the right ventricle is called the *pulmonary* artery because it carries the blood to the lungs. The one from the left ventricle is called the *aorta.* It is the large tube that curves up over the heart, as shown in Fig. 14.

The aorta sends off branches to the head, arms, legs, trunk, and, in fact, to every part of the body. These branches divide into finer and finer branches until at last the artery is so small it cannot be seen without a microscope. Some of the fine branches are shown in Fig. 18, but a line cannot be made on paper as fine as the smallest arteries.

Capillaries—The capillaries are tubes still finer than the finest arteries. When the blood reaches the end of an artery, it passes into the capillaries. The plan of the capillaries is shown in Fig. 19. All arteries carry blood into capillaries, and all capillaries pass the blood on into veins.

It is while the blood is slowly moving

through the capillaries, that the food oozes through to the cells.

All parts of the body are filled with capillaries. It is not possible to push a fine needle

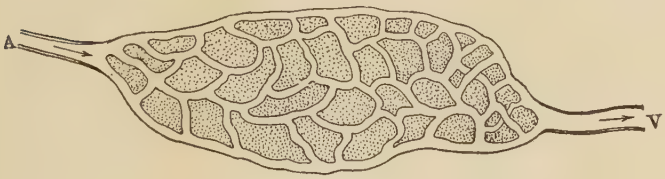

FIG. 19.—Capillary.

through the skin without piercing one or more of these fine blood-tubes and letting out some blood. They are everywhere in muscle, bone, nerves, and all live parts of the body.

The whole use of the heart and the arteries is to keep the capillaries filled with blood.

Veins.—Blood moves through capillaries at the rate of only about one inch in a minute. This gives time for the liquid food in the blood to get to the cells, and for the waste in the cells to get into the blood.

The blood is then collected by a *vein*. Veins are at first very small ; but a great num-

ber of them unite and form larger and larger ones, just as many small streams of water often unite to form a large river. All veins are at work carrying blood back to the heart after it has passed through capillaries.

FIG. 20.—Valves in a vein.

Veins do not have thick walls, like arteries, but they have many valves, while arteries have none. These valves are only small pockets on the inside of the vein. When the blood flows towards the heart the valves do not hinder it, for they are pushed up against the side of the vein. But if the blood starts to flow in the other direction, the pockets fill up and close the vein.

Experiment 7.—Bare the arm and notice the numerous blood-vessels just under the skin. These are all veins. They are carrying blood up the arm towards the heart. Grasp the arm tightly and notice that the veins will

soon become swollen with blood on the side next to the hand. Notice also that knots appear here and there along the veins. These are caused by the valves.

All the smaller veins from the parts of the body below the heart are joined to one very large vein which carries the blood up to the heart. A short piece of it can be seen in Fig. 17, *b*. All the veins from the head, arms, and other parts above the heart unite in one large vein which carries the blood down to the heart. (Fig. 17, *c*.)

Blood.—Blood is a liquid which the heart forces around and around through the arteries, capillaries, and veins. The blood has three important duties to perform: (1) To take up the food after it is digested, and distribute it to the cells in all parts of the body (2) To take up oxygen which we breathe into the lungs, and carry it to the cells. (3) To gather up waste matter and carry it to the lungs, kidneys, or skin, where it is cast out.

The blood is made up of a thin liquid in

which a great number of corpuscles are always floating. These corpuscles are of two kinds, the *red* and the *white*.

Red corpuscles.—Fresh blood is always a bright red, but the color is all due to the red corpuscles. These little bodies are so numerous that they make all the blood look red. The red corpuscles are very small discs of solid matter. They have the shape shown in Fig. 21. It would take over 10,000 of them, placed one upon the other, to make a pile one inch high.

FIG. 21.—Red blood-corpuscles.

These little discs are a very important part of the blood. They are the oxygen carriers. Every time they pass through the lungs each one takes up a small load of oxygen and carries it out to the capillaries, where the oxygen is given up to the cells.

While the corpuscle is loaded with oxygen it is a bright red color, but after it has passed through the capillaries and lost the oxygen, it

is no longer red, but purple in color. So the blood in the arteries is red, and in the veins, purple. The only exception to this is that the artery from the right ventricle to the lungs carries purple blood, while the vein from the lungs to left auricle carries red blood.

Experiment 8.—Pierce the skin of the thumb with a fine needle, and let out a small

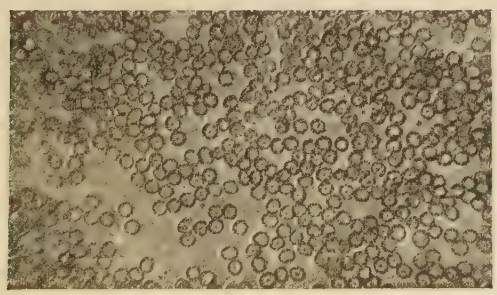

FIG. 22.—Microphotograph of red corpuscles.

drop of blood. Smear it upon a clean slip of glass so that it is spread out very thin. Then place the glass under a compound microscope and look for red corpuscles. They will not appear very red unless a great number of

them are seen together. Fig. 22 is a photograph of human blood as seen through a strong microscope. The blood on the spot that was photographed was so thin it could scarcely be seen with the naked eye.

White corpuscles.—White corpuscles are found floating in the blood with the red ones. They are larger than the red, but there are not nearly so many of them. They are single cells and have a nucleus. Their movements and manner of life are very much like that of the amœba. A white corpuscle may rest and float along in the blood, or it may slowly move itself about. When it wishes, it can stretch itself into a fine thread and can go right through the wall of a blood-vessel into other parts of the body.

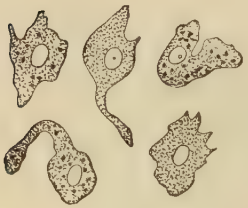

FIG. 23.—White blood-corpuscles.

The use of the white corpuscle.—The white corpuscles are of great service to the body. They are all the time in search of any

small particles that would do the body harm, and, if they can, they will permit nothing to be in the blood or muscles, or other parts of the body, unless it rightly belongs there. When one cuts his finger, it may become very sore. This is because there are always many little live germs in the air and on the skin, which get into the cut. They find good food there, and will multiply and live there unless they are destroyed. When this happens, the white corpuscles will gather around them in such numbers that the wound will become swollen and inflamed. They attack the little enemies that do not belong in the body and try to destroy them. In most cases they will succeed and the enemy will be driven out, but many of the white corpuscles lose their lives in the conflict, and the white matter, called pus, which appears in the sore, is composed of their dead bodies.

So we may think of the white corpuscles as a kind of standing army within the body. When the health is good, the standing army will be strong and can easily repel any enemies

that try to get in. When the health is bad and the body weak, one can more easily catch a disease because his standing army is weak.

Blood-clot.—The body has many ways of keeping itself well, fighting off disease, and healing up wounds. The doctor could do very little for the body if it did not do a great deal for itself.

A slight cut would soon let out all the blood, and life would cease, if there were no way to stop it; but nature has a way of checking its flow by forming a blood-clot in the wound. While in the blood-vessels the blood is thin, but as soon as it is outside it becomes quite thick. It would be very difficult to stop bleeding at the nose if a blood-clot did not stop the end of the fine artery from which the blood comes into the nose.

When a large artery is cut, the blood comes out so fast that the clot cannot stop it, and the surgeon must be called to tie the end of the artery.

The pulse.—The pulse beats as often as the heart does. It can be felt at any place where an artery, of good size, runs close to the surface. It can be most easily felt and counted at the wrist, just a little above the thumb.

The arteries are full of blood all the time, and every time the left ventricle contracts it forces more blood into the aorta. This causes a pulse, or wave, to run out through all the branches of the aorta. This is what we can feel at the wrist.

Experiment 9.—Break or cut off a piece of mirror about as large as a penny, or smaller. Fasten it to the wrist with a piece of chewing gum, at the point where the pulse can be most plainly felt. Now stand at a window and hold the mirror so that the sunlight, falling upon it, will be reflected to the ceiling of the room. The arm must be held still, and the pulse will tilt the mirror so as to make the bright spot on the ceiling move through a distance of one foot or more.

Change in the size of arteries.—The walls of the arteries are provided with mus-

cles which run around the arteries. When these contract, they make the tube smaller and less blood can get through. When they relax, the tube gets larger and more blood flows. This is all regulated by nerves which are connected to these muscles. When any part of the body needs more blood, the arteries that carry blood to that point will open and let more flow. When one goes out on a cold day, the small arteries under the skin will contract and keep the blood in nearer the centre of the body. This keeps the heat from escaping too fast.

Different paths of the blood in its circuit.—When blood is forced out by the heart through the aorta, it goes to all the capillaries in the body. But the part that goes to the stomach and intestines, where the fresh food is taken up, is gathered up by a large vein, called the *portal vein*, and carried to the liver. In the liver this blood is changed and purified, as has already been explained, and then carried up by a large vein to the heart.

Another branch from the aorta carries blood

to the kidneys. There the poisonous urea and a large amount of water are taken out. This blood, too, is then emptied into the large vein that leads up to the heart.

The large artery from the right ventricle carries the blood to the lungs, where water and carbon dioxide are taken out of it, and oxygen is taken up by the red corpuscles.

While this is going on, other portions of the blood are out in the muscles, the bones, the skin, and every part of the body, feeding the cells. So the blood is flowing through many different circuits at the same time.

Beating of the heart.—If the hand be placed on the left side, at a point between the fifth and sixth ribs, the beating of the heart may be distinctly felt. The two sides of the heart work together. Both auricles contract at the same time and fill the ventricles. Then the two ventricles contract,—the right one sending its blood to the lungs, and the left one forcing blood into the aorta.

The ventricles are strong, and when they

contract they cause a movement which is called the heart-beat.

If the ear be pressed against the chest, right over the heart, the closing of the heart's valves can be heard. Their sounds are nearly like loob-dûp.

Work and rest of the heart.—The heart must work hard, day and night, from the beginning to the end of one's life. It beats about seventy times every minute. Sometimes more and sometimes less.

The heart does not seem to rest at all; but it does rest nearly half the time, though its periods of rest are only the short times between heart-beats.

The heart needs a great deal of food to keep it strong for the hard work it has to do. It does not get food from the blood inside of it, but the first artery that branches off from the aorta carries fresh blood to the muscles of the heart.

Good blood.—Good blood and a good circulation are almost sure to keep the body in

good health. The body may continue to live when the blood is poor, but it cannot be strong and healthy. Several things are needed to make good blood.

(1) Sufficient food of the proper kind must be digested every day and taken into the current of blood. The blood can get only what we eat and digest for it. If we eat poor food, the blood will feed it to the cells, and, of course, the whole body will have to suffer.

(2) Blood is not good unless it contains plenty of oxygen. The oxygen we breathe is just as important as the food we eat.

(3) Some waste matter is constantly being produced by the action of the muscles and nerves, and this goes into the current of blood. The blood would soon become very impure if it were not for the work of the liver, lungs, kidneys, and other organs, that take these impurities out and purify the blood.

(4) The nerves must be able to control the size of the arteries, so that the right amount of blood will be carried to the place where it is most needed.

How exercise helps circulation.—We have explained that blood will be sent out to different parts of the body in proportion to their needs. If the right arm is made to work harder than the left one, more blood will flow to it. The more work the cells do, the faster they use up their food, and so they need more blood.

Now, if one takes some active exercise in which many muscles are made to do work, more blood will be needed in many parts of the body. The arteries will become larger and the heart will beat faster. Every organ of the body is aroused to activity. The food is rapidly used up and a sensation of hunger begins. Hunger is simply the call for more food.

Alcohol and the heart.—When alcohol is taken into the body, it makes the heart beat more rapidly. In some cases of sickness, when the heart gets very weak and is unable to keep the blood going, doctors give some brandy or whiskey to stimulate its action. This makes some people think that alcohol is good for the heart; but it is found that, after

the excitement caused by the alcohol has passed away, the heart is weaker than before.

This is the reason some good doctors will not give alcohol for any kinds of sickness.

After one has used beer, whiskey, or other alcoholic drinks for a long time, the heart often gets weak and unable to keep up a good circulation. This is because some of the muscles in the walls of the heart change to fat. Fat is not able to do any work, and so the heart loses its ability to force the blood through its circuit in the body.

Alcohol and arteries.—The size of the arteries is controlled by the nerves. If the nerves do not act, the arteries will stand wide open. Some parts of the body will then get too much blood, and other parts not enough.

A large dose of alcohol will paralyze the nerves for a time, and then there is no way to regulate the flow of blood.

This can be seen in the red face and nose, and the bloodshot eyes of the drunkard.

When one is exposed to cold weather, the

blood-vessels in the skin should contract and keep the blood within the body. But alcohol will take away this power of the nerves, and the blood can flow close to the skin. This seems at first to make the body warmer; but the heat is rapidly getting away, and after a time the whole body will be colder than it would have been without the alcohol.

Alcohol and blood.—We have already explained what is needed to make good blood. Unless digestion is good, the blood will not be good, and we have seen how alcohol interferes with digestion. Unless the liver, lungs, and kidneys keep the blood pure, it will carry harmful substances to the cells. Alcohol hinders the work of these organs and gives them more work to do.

Tobacco and circulation.—It is claimed by good physicians that much of the heart trouble and heart failure is caused by the use of tobacco. The nicotine in tobacco makes the heart palpitate and beat in an irregular manner.

This effect is most plainly seen in young people, who, if they use tobacco at all, are almost sure to use it to excess.

The effect on the blood and the organs of circulation soon shows in the bad health of the whole body.

QUESTIONS.

1. Why is it necessary for the blood to circulate?
2. How does the blood get the food which it carries to the cells?
3. Describe the liver.
4. What three things does the liver do?
5. What is the thoracic duct, and of what use is it?
6. What are the organs of circulation?
7. What does the heart do?
8. Where is the heart?
9. What is the pericardium?
10. What is meant by *right heart* and *left heart?*
11. Describe the cavities of the heart.
12. Make a drawing and explain the operation of a set of valves.
13. Why are valves needed in the heart?
14. How many valves in the heart? Name them.
15. What are arteries?
16. What is the aorta?
17. What happens in the capillaries?

18. Where do veins begin?

19. What is the difference between an artery and a vein?

20. Why are valves in veins?

21. Into which cavity of the heart do the veins empty the blood?

22. Which part of the heart has only red blood?

23. What three things does blood do?

24. What makes the blood red?

25. What do the red corpuscles do?

26. When does blood become purple?

27. How can the red corpuscles be seen?

28. What are white corpuscles?

29. What do white corpuscles do?

30. Explain the use of a blood-clot.

31. How many times does a pulse beat?

32. What causes the pulse?

33. How can the beating of the pulse be made visible?

34. How is the flow of blood regulated?

35. When the heart beats, what is it doing?

36. What sound does the heart make?

37. What is necessary to make good blood?

38. How does exercise affect circulation?

39. What effect does alcohol have on the heart?

40. How does alcohol affect the arteries?

41. How does alcohol cause the blood to be impure?

42. What is the effect of tobacco on circulation?

CHAPTER VI

RESPIRATION

Need of air.—Man and all animals need *air* as well as *food*. Neither one would be of any use without the other. We must constantly live in the air, and must breathe a large quantity of it into the lungs every day. We can eat enough at one time to last for several hours, but we cannot keep from breathing for even one minute. Because the body is all the time surrounded by air, it is not necessary for us to have any way of storing it up.

The part of the air that we need most is the *oxygen*. Oxygen is the very breath of life, and we have to depend upon it for every minute of our existence.

The operation of breathing, and the purpose of air in the body, will be explained in this chapter.

What respiration is.—Respiration is only another name for breathing. Inspiration is the act of taking air *into* the lungs. Expiration is the act of breathing air *out* of the lungs. The two together are called respiration.

We have said that food is like the coal which burned under the boiler of a steam-engine. Breathing is like the draft of air which makes the coal burn.

In the steam-boiler the air enters at one end, and the smoke and gases are carried away by a smoke-stack at the other end.

In the body the fresh air goes in through the windpipe and the bad air comes out the same way.

It is the oxygen in the draft of air that makes the coal burn under the boiler, and that produces the heat and power of the engine.

It is the oxygen in our breath that makes the food in the cells slowly burn, and that warms the body and gives us ability to do work.

Combustion in the body.—Combustion is the union of oxygen with other substances. If this goes on very rapidly, we say the substance is being burned, and a blaze is produced, as in the combustion of wood and coal. A great number of substances will unite with oxygen in this way; but the combustion of some substances is very slow, and so they never get very hot. It is this slow kind of combustion that takes place in the body.

Experiment 10.—Secure two pieces of magnesium ribbon, each about two inches long. Hold one piece with a pair of pliers and light it with a burning match. It will burn brilliantly, but in a second or two it will all be consumed except some white ash.

Place the other piece in an open wide-mouthed bottle and sprinkle upon it a few drops of water. In a week or two it will also be consumed, and only the white ash will remain.

In both cases the magnesium was burned up by uniting with oxygen. The same amount of heat was given out in both cases.

This will illustrate what is meant by the slow combustion of food in the body. The food does not burn as a match burns, but more like the magnesium in the bottle.

Why we need to breathe.—Many of the very small animals have no lungs and do not breathe. But they must have oxygen, and they take all they need right through the surface of their bodies. Even a frog can get a good part of his oxygen through his skin. In man and all the other warm-blooded animals, so much oxygen is needed that there must be special organs to get the oxygen into the blood. So we breathe it into the lungs, and there the red corpuscles of the blood take it up and carry it out to the cells in every corner of the body. It is in the cells where the slow combustion of the food occurs.

Organs used in respiration.—The organs used in breathing are the *nostrils*, the *pharynx*, the *larynx* (voice-box), the *trachea* (windpipe), the *bronchi*, the *bronchial tubes*, and the *air-sacs*. The air is forced in and out

through these passages chiefly by movements of the ribs and diaphragm.

All of the air-passages are lined with mucous membrane, and nearly all the cells on the surface of this membrane have cilia, as shown in Fig. 24. The use of the cilia will be explained a little farther on.

FIG. 24.—Ciliated cells.

The nostrils.—The nostrils have several important uses, but they are chiefly intended for the entrance of air into the body. Several things show that air should always be inhaled through the nose and not through the mouth.

(1) The mucous membrane of the nose is always moist with a sticky mucus, which is made by the mucous glands. The dust and minute living germs, some of which are always floating in the air, are stopped in the nostrils by the mucus. Thus the nostrils act as a strainer of the air.

(2) A thick net-work of blood capillaries is just under the mucous lining, so that a large

supply of warm blood always circulates about the air as it is entering the body. In this way the air is warmed before it reaches the lungs.

(3) The nerves of smell are located in the nostrils, and that, too, shows that the air should be breathed only through the nose.

The larynx.—The air passes through the nostrils into the pharynx, which is the box described on page 52. Here the air enters the larynx.

The larynx is the voice-box at the top of the windpipe. It is made of cartilage, and can be plainly felt just under the chin. "Adam's apple" is a projection of one of the cartilages of the larynx.

Two membranes, called the vocal cords, are stretched across the larynx. The slit between the cords is the glottis. In ordinary breathing, the glottis is wide open, as shown in Fig. 25. When we wish to use the voice in speaking or singing, the cords are drawn close together, and air from the lungs is forced through them. The air makes the cords vibrate, and thus the

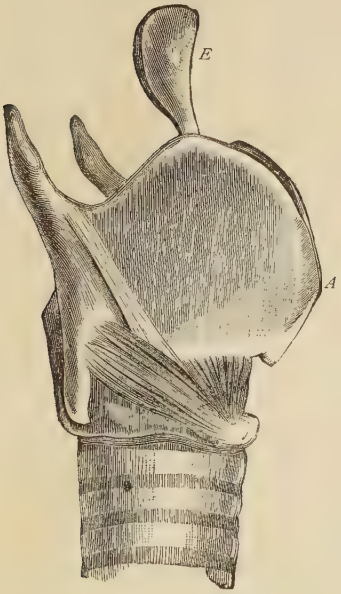

FIG. 25.—The larynx. *E*, epiglottis; *A*, "Adam's apple."

FIG. 26.—Vocal cords. *V V*, true vocal cords; *P P*, false vocal cords; *L*, epiglottis. *A*, cords open, as in breathing; *B*, cords drawn close together, as in speaking and singing.

sound is produced. When the cords are thick and long, the voice will be deep and heavy; when they are short and thin, the voice will have a high pitch.

FIG. 27.—Apparatus to illustrate the action of the vocal cords.

Experiment 11.—Get from a dentist some rubber, such as he uses for rubber dam. Stretch two pieces over the end of a lamp-chimney, or tube of any convenient size, so that the edges are very nearly together. Close the mouth over the end, *A*, and blow through the tube. Stretch the rubber more tightly and notice that the pitch of the sound will be raised.

Tie the rubber in place, and then place both hands about the end, *B*, so as to make a cavity like the mouth. By opening and closing the hands, while blowing through *A*, try to make the apparatus say *mamma*. This will illustrate the operation of the cords and mouth in speaking.

The trachea and bronchi.—The *trachea*, or windpipe, is a tube about one inch in diameter and four and one-half inches long. At

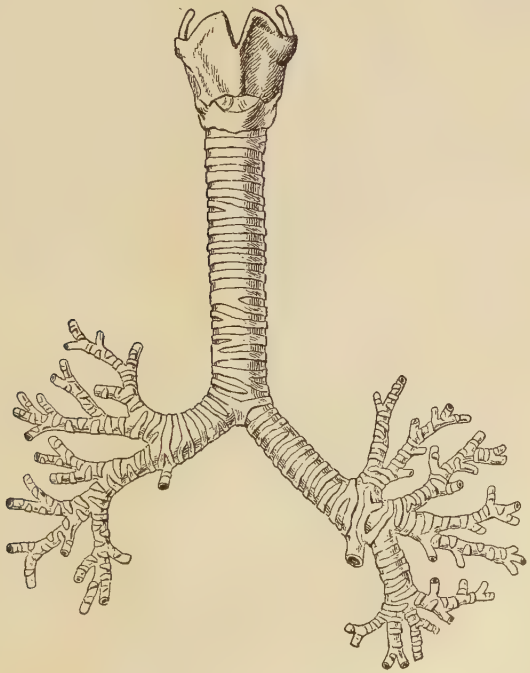

FIG. 28.—Trachea and bronchi.

its lower end it branches to the right and left, forming the two *bronchi*, one of which goes to each lung.

The trachea is kept open all the time by rings of cartilage. These are shown in Fig. 28.

The whole trachea and bronchi are lined with mucous membrance, with its ciliated cells. The cilia are hairlike projections which constantly wave back and forth, but their motion upward is faster than the motion downward.

In that way any phlegm or small particles that get into the windpipe are moved towards the throat, where they can be coughed up.

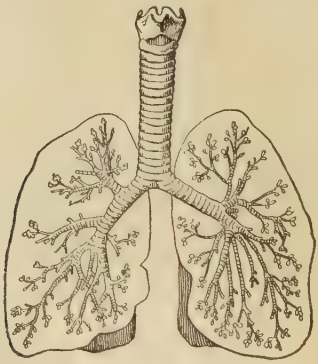

FIG. 29.—Bronchial tubes.

Bronchial tubes.—The bronchi reach to the lungs and there they divide into many branches, forming the *bronchial tubes.* These divide into finer and finer branches, and at last

end in an expansion called the *air-sac*. A few of these sacs are shown in Figs. 29 and 31. When we take a deep breath, all the sacs are filled with air. There are more than four million of air-sacs in the lungs.

The lungs.—The two lungs, the right and left, nearly fill the chest. The right one is a

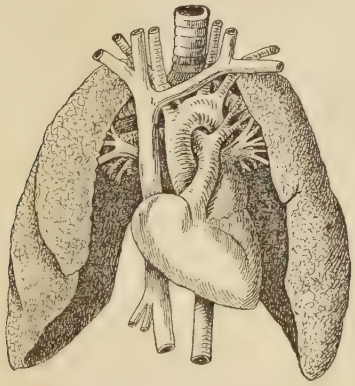

FIG. 30.—The lungs.

little larger than the left, the two weighing about three pounds.

The lungs are a kind of spongy substance, being made up of bronchial tubes, air-sacs, and numerous arteries and blood capillaries.

The walls of the air-sacs are very thin, and the blood flows through capillaries just outside,

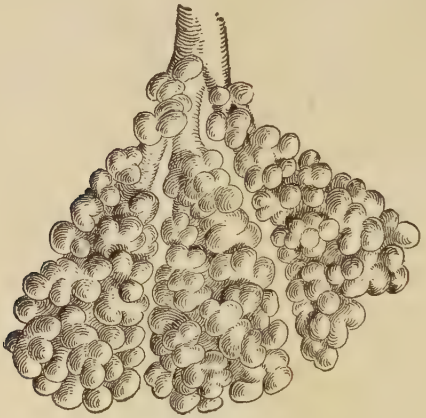

FIG. 31.—Air-cells.

so the oxygen can easily go through to the blood, and some impurities in the blood can come out into the air-sac.

The lungs are covered with a smooth membrane called the *pleura*.

Inhalation.—Inhalation is the act of filling the lungs with air. Air presses with the same force in all directions, and so, if the chest be made larger, the air will rush in until the press-

ure inside is the same as that outside. The chest is changed in size by the action of the ribs and diaphragm.

The ribs do not run straight around the chest, but are lower in front than they are behind. If they be raised in front, the chest will be made larger. This action is plainly shown in Fig. 32.

The diaphragm is a strong partition of gristle and muscle. It stretches clear across the trunk of the body and forms the floor of the chest. It is bulged up in the centre, and has a shape something like a butter-bowl turned upside down. When the muscles around its edge

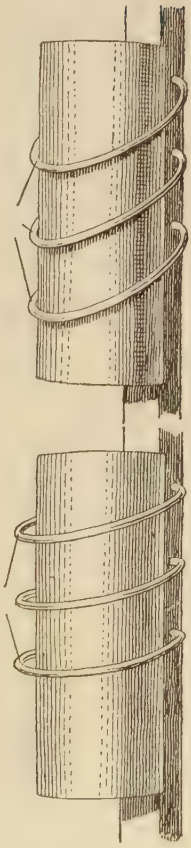

FIG. 32.—Showing how the elevation of the ribs makes more room in the chest.

contract they make it flatter, and the chest is in that way made larger.

The ribs and diaphragm work together in this manner every time we take a breath.

Exhalation.—Exhalation is the act of forcing air out of the lungs. This is done by making the chest smaller. The ribs sink down in front and the diaphragm bulges up. Very little effort is needed in ordinary breathing: but when we wish to breathe out a large amount of air suddenly, as when we loudly call or sing or blow, the muscles in the abdomen push the liver and stomach hard against the diaphragm. This pushes the diaphragm up and forces the air out of the lungs.

Amount of air in the lungs.—The lungs of a man will hold about 330 cubic inches of air, but in ordinary, quiet breathing only about 30 cubic inches are inhaled and exhaled at each breath. After the lungs are filled full, one can breathe out 230 cubic inches of it, but 100 cubic inches always remains in the air-cells.

When one is at rest he can get enough of oxygen without filling the cells at every breath, but when he is at hard exercise he must breathe deeply and about twice as fast. This is because food is being rapidly consumed in doing hard work, and so more oxygen must be supplied. It is like turning on a good draft of air to get up steam when a locomotive has to pull a train up grade.

A man will breathe about 18 times a minute when at rest, but more than 30 times while at hard work. The weight of the air that is breathed in a day is seven or eight times as great as the weight of the food that is eaten.

Experiment 12.—Count the number of times you breathe in one minute. Then run one hundred yards and back, and count again. This may be made an interesting exercise in class. Let one or two keep time while each pupil counts the number of breaths he takes in a minute. Then let the class arise and take some vigorous physical exercise and count again.

Experiment 13.—Make up a good soap solution such as can be used in blowing large bubbles. Take a full breath and blow as large a bubble as you can with one breath. Let some one hold a ruler close to the bubble while you are blowing and measure as nearly as possible the diameter of the bubble when it is largest. Then calculate the size of the bubble in cubic inches, and you will have the amount of air breathed out in one breath.

Composition of air.—The air is composed of several different gases, all well mixed together. When we breathe the free out-door air we always inhale some of each of the gases.

The great bulk of the air is oxygen and nitrogen. About one-fifth of all the air is oxygen, and four-fifths nitrogen.

The four gases of the air are *oxygen*, *nitrogen*, *argon*, and *carbon dioxide*, and they are present in these proportions.

	Per Cent.
Oxygen,	21
Nitrogen,	78
Argon,	1
Carbon dioxide,	0.03

Oxygen.—Oxygen is the most important of all the gases in the air. We breathe the air to get the oxygen that it contains. It is the oxygen that makes the coal, wood, oil, and many other substances burn. It is the oxygen that combines with the food in our bodies, and gives us ability to do work and also keeps us warm.

Oxygen is a very active gas and will unite greedily with many other substances. We have to keep a fire department to prevent the union of oxygen with the material of our stores and homes.

Experiment 14.—Light a short piece of candle and place it on a smooth table. Cover it with a glass tumbler and the candle will soon "go out." We may say that it died because it could not get its breath. Water will put out a fire by covering the burning material so that the oxygen cannot get to it.

Nitrogen.—Nitrogen forms the largest bulk of the air, but it is not active. It will

put a fire out. Its chief use in breathing is to keep us from getting the oxygen too rapidly.

The nitrogen is breathed into the lungs and then exhaled without any change.

Argon is very much like nitrogen, only even less active.

Carbon dioxide.—There is only a very small per cent. of carbon dioxide in the air, but it has some very important uses. It is a food for all plants. All animals live on plants, so that, indirectly, carbon dioxide is a food of animals.

Man and other animals breathe in the oxygen and breathe out the carbon dioxide. Plants breathe in carbon dioxide through their leaves and breathe out oxygen; so each throws out into the air what the other wants.

The exchange in the air-cell.—When wood and coal are burned, a large amount of carbon dioxide is given off in the form of a gas. This is carried up the chimneys of our houses and factories and escapes into the air.

When the food is burned within the body this same gas is always produced, and the body must get rid of it in some way.

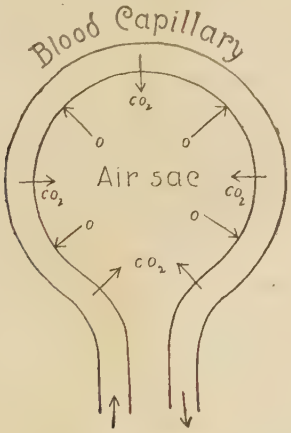

FIG. 33.—Exchange of gases between air and blood.

While the fresh red blood is flowing through the capillaries of the body it gives up its oxygen to the cells, and takes up in exchange the carbon dioxide. The blood is then purple in color and starts back at once for the heart, which sends it to the lungs.

In the lungs the purple blood is made to pass through fine capillaries just outside the air-sac. The carbon dioxide in the blood can

then pass out into the air-sac, and at the same time the oxygen in the air-sac can pass into the capillaries to the red corpuscles.

When the expired air is examined it is found that the nitrogen and argon have not been changed, but much of the oxygen was taken out of it and much carbon dioxide added to it. The per cent. of oxygen being now 15 and of carbon dioxide 4.

Experiment 15.—Slack a piece of lime and put a large handful of it into a quart of water in a jar. Shake and set aside till the lime settles. The liquid will become clear in an hour or two. Carefully pour off some of the clear liquid into a test-tube or bottle. Blow into it through a glass tube or rye straw. Soon the clear liquid will have a milky appearance. This is a test for carbon dioxide. If pure air had been blown through the tube, the liquid would have remained clear.

How air is made impure.—The air in the open country is nearly always good to breathe

because the volume of air is so large that any small impurities would not be noticed.

The air in living rooms, school buildings, public halls, churches, and railway carriages is most liable to be impure. If these rooms are tightly closed, then there is only a limited quantity of oxygen within.

When the room contains a number of people, each will use some of the oxygen at every breath and breathe out some carbon dioxide. In a short time the air will be unfit to breathe, as will be shown by the drowsiness, headache, or restlessness of the occupants of the room. This is caused not only by the scarcity of oxygen and the presence of a large amount of carbon dioxide, but the exhaled breath also contains some poisons which make the air in a close room unfit to breathe. Burning lamps also use up the oxygen and give off carbon dioxide, but they do not poison the air as much as our own breath does.

Particles afloat in air.—The air always contains many living germs and fine particles

of dust. Even when the air looks perfectly clear, it is filled with fine particles that are too small to be seen except by aid of the microscope. The fine particles of lifeless matter in the air cannot do much harm, for the most of them are caught in the nostrils and air-pas-

FIG. 34.—Dust in air.

sages before they reach the lungs. When air is very dusty it should be avoided, because it will irritate and inflame the mucous membrane of the air-passages.

The greatest danger in breathing dusty air is not because of the dust itself, but because of the minute living germs which are quite likely to be floating with the dust. The little germ which is most likely to be floating in the air is the one that causes consumption of the

lungs. These are so small that it takes a very strong microscope to see them. Fig. 34 shows how they look. The sputum of a consumptive is full of these germs, and, if it dries on the street or elsewhere, the wind will drive it

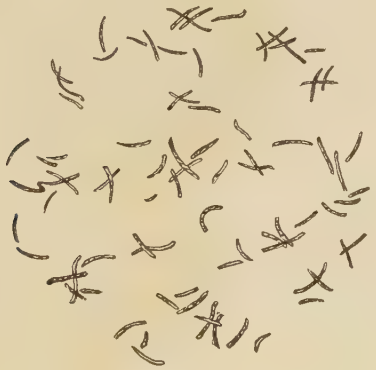

FIG. 35.—Bacteria of consumption.

about with the dust. When one breathes such air there is great danger that he will get the same disease.

We cannot avoid breathing some dust and some living germs. But we can be careful to have the air as free from them as possible. Best of all, it is possible to keep the body and lungs in such a healthy and robust condition

that the germs cannot get a lodgement there, but will be breathed right out again.

Ventilation.—The way to keep the air fresh is to have a fresh supply coming into the room all the time, and the foul air constantly going out. This is called ventilation, and there are many ways by which it may be done.

A fire in a stove or fireplace will cause a draft which will take considerable air up the chimney, and fresh air will then come into the room through cracks at the doors and windows, but this will be sufficient for only one or two persons. It would not be enough for a school-room or hall.

Rooms that are heated by hot air are mostly well ventilated ; but rooms heated by steam or hot water in radiators are mostly poorly ventilated, for the same air stays in the room all the time, unless some extra arrangement is made for ventilation.

Good air is as necessary to good health as good food. The only way to get good air is to give close attention to the ventilation of the

room in which you live, particularly in the winter time, when the room must at the same time be kept warm. Warm air may be just as fresh as cold air.

Each person should be provided with 3000 cubic feet of fresh air every hour.

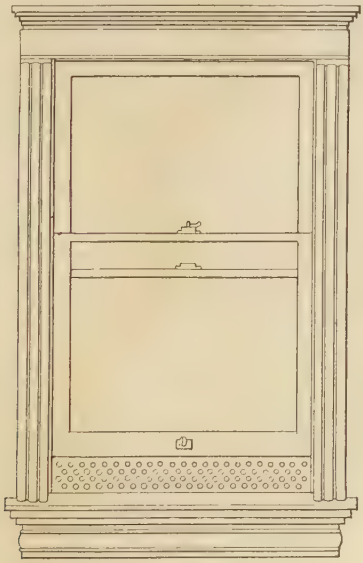

FIG. 36.—Ventilation by window.

Window ventilation.—It is often necessary to admit fresh air at a window. This may be done even in cold weather, without

chilling the air too much, by raising the lower sash three or four inches and fitting a board in at the bottom. Or, as shown in Fig. 36, a still better plan is to fit in below the sash a metal box with perforated sides. The box may easily be made of zinc and should be about one inch thick, four inches wide, and long enough to fit into the space below the sash. The holes in the sides should not be opposite each other, and then no direct draft will be felt near the window.

At times when the wind is strongly blowing the ventilation is often sufficient without raising the window.

Sleeping-room ventilation.—We breathe all night, and it is important that the air in the bedroom be kept fresh all night. In some hospitals the patients sleep in tents or on an open veranda, even in cold weather. The abundance of fresh air does them good.

It is better to sleep in a cold room, because then one can open the windows and admit plenty of air, and he will provide enough of

covers before he goes to sleep, and so will not be chilled during the night.

Good breathing.—The air in a room may be pure, and yet we will not get sufficient oxygen unless we can inhale it in the proper manner.

If one sits in a cramped position, the movements of his chest are hampered.

A tight bandage or belt about the waist will make it impossible to breathe properly. The lungs and other organs are pushed out of their natural position, and the ribs and diaphragm are not free to move. When the supply of oxygen is small, the body is weakened; just as when the draft to a fire is shut down, the fire burns low.

It is not necessary to fill the lungs every time we breathe, but at least once each day a few minutes should be taken for breathing exercises. These should always be taken at some place where the air is sure to be pure and abundant. Before an open window, on the porch, or out in the fields or park, are good places for breathing exercises.

Experiment 15.—Take a position before an open window. Be sure the clothing is light and loose. Stand erect. Slowly raise the arms from the sides till the hands meet high over the head. While the arms are rising, be filling the lungs with air. Hold the air for a short time. Separate the hands and slowly lower them to the side, at the same time exhaling the air. Repeat this till you feel a little dizzy. This exercise should be repeated every morning on arising from bed, or at some regular time, till it becomes a habit, and then it will not be neglected.

This is only one of many valuable breathing exercises. The value in any of them consists in "keeping them up."

Effect of alcohol on breathing.—Good health depends very much upon good breathing and the perfect oxidation of food, just as a good fire depends on a good draft. Both the breathing and the circulation are regulated every moment by nerves from the brain. Alcohol in large doses, or by continued use of

small doses, interferes with this nervous control. The capillaries of the lungs relax. They become crowded with blood. This causes inflammation, and the air-cells are crowded so they cannot properly expand.

Extra work is at the same time thrown onto the lungs, in getting rid of the alcohol and other poisons which are caused by the alcohol.

The lungs at all times have enough to do in giving oxygen to the blood and casting out the waste which is all the time being produced in a healthy body. Alcohol adds to the work of the lungs, and at the same time decreases their ability to do it.

Anything that interferes with and hinders the work of an important organ, such as the lungs, weakens the whole body. At such times the body is less able to fight off the disease germs which are trying to get into it. The white corpuscles which guard the body are weakened by the alcohol.

An old drinker will easily get a disease, and it is hard for him to get well.

Tobacco smoke and the lungs.—It would be better if no one used tobacco in any way. A *moderate* use of good cigars by a full-grown man may do the body very little or no harm. An occasional pipe of tobacco appears to have no injurious effect on the man who is used to an out-door life. But tobacco is seldom used with moderation by those whose work is such that they can smoke at the same time, and so it often does serious injury to the throat, lungs, and other organs of the body.

The greatest injury done by tobacco is from its use by youth who are still growing. There is no doubt that the growth of both the body and the mind of a boy are stunted by the use of tobacco in any form.

By far the worst use of tobacco is the smoking of cigarettes. This is due chiefly to the manner in which cigarettes are smoked, and to the ease with which they may be used to excess.

The cigarette smoke is nearly always inhaled, that is, it is drawn down into the air-

cells of the lungs. There the poison in the tobacco easily passes into the blood, and is carried out to the brain, nerves, muscle, and all other parts of the body.

It is very easy to get into the habit of smoking cigarettes, and it is hard to break away from it.

A boy who smokes cigarettes runs a great risk of spoiling his prospects of success in life.

QUESTIONS.

1. Why do we have to breathe so often?
2. What part of the air do we need?
3. What is respiration?
4. What makes coal burn?
5. What is meant by combustion?
6. Describe an experiment to illustrate slow combustion.
7. Why do we have special organs of respiration?
8. Name all the organs used in respiration.
9. Give two good reasons for breathing through the nostrils.
10. Describe the larynx.
11. Describe the vocal cords.
12. Have you performed Experiment 11?

13. Describe the trachea.

14. What are the bronchi?

15. What is the use of the ciliated cells in the wind-pipe?

16. How many air-sacs in the lungs?

17. How does the air get from the bronchi to the air-sacs?

18. Describe the lungs.

19. What makes air go into the lungs?

20. What forces air out of the lungs?

21. How can we make the voice very loud?

22. How much air will the lungs hold?

23. Why do we breathe faster when we are hard at work?

24. How many times do *you* breathe in one minute?

25. How can you count the number of cubic inches of air in one breath?

26. Name four gases in the air, and tell how much of each kind.

27. Which is the most important gas? Why?

28. What does the nitrogen do?

29. What is the use of the carbon dioxide?

30. What exchange is made between the blood and the air in the air-sacs?

31. Have you tested for carbon dioxide in your breath?

32. Why is it harmful to breathe dust?

33. How are consumption germs carried in the air?
34. What is ventilation?
35. Tell several ways of ventilating rooms.
36. What is good breathing?
37. Describe some good breathing exercise.
38. How does alcohol injure the organs of breathing?
39. Why is cigarette smoke so injurious to the body?

CHAPTER VII

THE SKELETON

Use of the skeleton.—The skeleton is the bony frame-work of the body. It has several important uses.

(1) It fixes the shape of the body. No matter whether we lie down or stand, the bones keep the body about the same height and shape.

(2) Bones protect many of the delicate parts of the body from injury. The skull surrounds the delicate brain, and the ribs protect the heart and lungs.

(3) Bones support many of the softer parts of the body and hold them in place. The organs in the thorax and abdomen are supported from the ribs and backbone.

(4) Many of the bones are used as levers to give motion to the body. The forearm is used as a lever when we bend the arm at the elbow and move the hand back and forth.

If it were not for the bones, the motions of our body would be slow and sluggish, and we could only crawl around.

Kinds of bones.—There are in all 206 different bones in the human body. These may all be put into four classes. The *long*, *short*, *flat*, and *irregular* bones. The bones in the legs, arms, and hands are long bones. Those in the wrist and ankles are short bones. Those in the skull, the ribs, the shoulder-blade, are examples of flat bones.

The irregular bones are such as have an irregular shape, like the vertebræ of the back-bone.

The cranium.—The cranium is a strong bony box which protects and supports the brain. It is made of several flat bones, which are joined together at the zigzag lines shown in the cut. This kind of joint is called a *suture*, because the bones seem to be sewed together.

There are 8 bones in the cranium :

1 *frontal*, the forehead.
2 *temporal*, at side of head, just above the ears.
2 *parietal*, one on each side, back of frontal.
1 *occipital*, at lower part of back of head.
1 *sphenoid* } forming the floor of the cranium.
1 *ethmoid* }

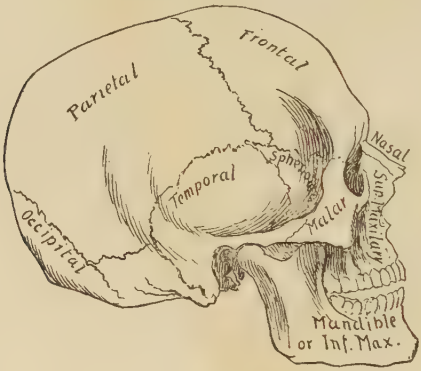

FIG. 37.—The cranium.

The spinal column.—A vertebra is one of the bones of the spinal column. One is shown in Fig. 38. It has a number of processes which extend backward and sideways. *a*, Fig. 38, is the process which can be felt when you rub your fingers along the backbone.

Through each vertebra is a hole, so that,

when they are placed one on top of another, the holes form a long tube. In this tube is found the spinal cord, sometimes called the marrow.

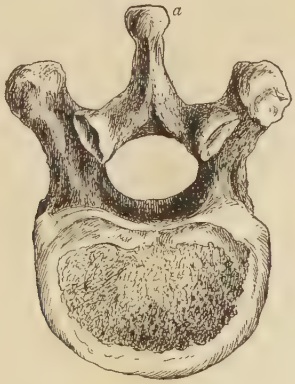

FIG. 38.—A vertebra.

The spinal column is formed of 26 separate bones, put together so as to form a column, as shown in Fig. 39. This column supports the head and body, and makes it possible for us to stand erect. There are five classes of bones in the spinal column :

7 *cervical* vertebræ, in the neck.
12 *dorsal* vertebræ, in the back.
5 *lumbar* vertebræ, in the small of the back.

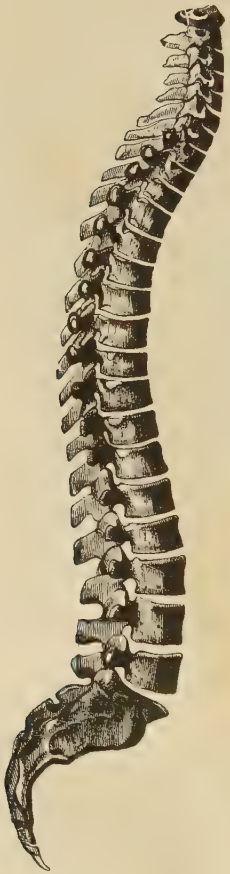

FIG. 39.—Backbone.

1 *sacrum*, made of five bones which grow together into one bone called the sacrum.

1 *coccyx*, at lowest point of the spinal column, made of four bones which grow together into one bone called the coccyx.

These are named in order from the top down.

The topmost cervical vertebra is called the *atlas*, and the next one, the *axis*. The head

FIG. 40.—Atlas on the axis.

rests on the atlas, and the atlas can freely turn on the axis. A pivot from the axis runs up through the atlas and holds it in place. The position of these two bones is shown in Fig. 40.

How the vertebræ are joined together.—It can be seen in Fig. 39 that the backbone is curved a little like the letter S. This helps to prevent any sudden jars to the head and

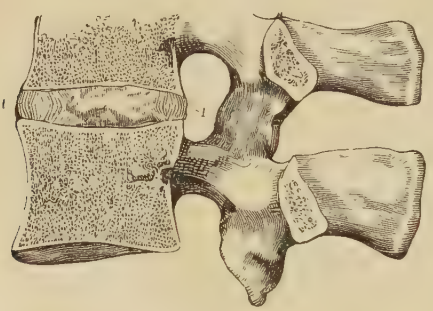

FIG. 41.—Section through two vertebræ, showing pad of cartilage, 1.

the organs of the chest. If the backbone were straight up and down, then the jar from jumping and running would be greater.

There is also an elastic pad of cartilage placed between the vertebræ, as shown in Fig. 41. The bones do not touch each other. Each pad is elastic like rubber, and so they act like a spring under a carriage to prevent jolting. They also make the backbone very flexible, so that we can easily bend the body in any direction.

The ribs.—The ribs are flat elastic bones that form the frame-work of the chest. There are 24 ribs, 12 on each side. One pair of ribs is jointed to each of the dorsal vertebræ,

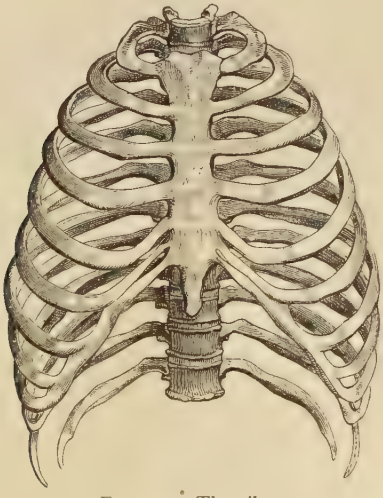

FIG. 42.—The ribs.

as may be seen in Fig. 42. In the front they are attached to the breast-bone by a flexible cartilage, except the two lower ones, which are not fastened in front.

The pelvis.—The pelvis is a large bony basin at the bottom of the trunk of the body.

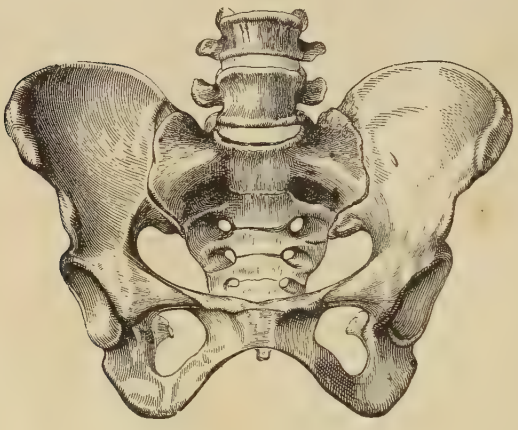

FIG. 43.—The pelvis.

FIG. 44.—The scapula.

It is made up of the sacrum and coccyx, which have already been explained as forming the lower end of the spinal column, and the large hip-bones, one on each side.

The collar-bone and shoulder-blade.—The collar-bone is a long bone running from the top of the breast-bone out to the shoulder. It is called the *clavicle*. There is one on each side.

The shoulder-blade is a broad, flat bone, shaped as in Fig. 44. It is called the *scapula*. There is one just back of each shoulder.

Bones of the arm and hand.—There are 30 bones in each arm. They are:

1 *humerus*, between shoulder and elbow.
2 *radius* and *ulna*, between elbow and wrist.
8 *carpal bones*, in the wrist.
5 *metacarpal bones*, in the hand.
14 *phalanges*, in the fingers.

The *humerus* is the largest bone in the arm. At its upper end it forms a joint with the shoulder-blade, at *d*, Fig. 44. At its lower end it is jointed to the radius and ulna.

The *radius* and *ulna* lie side by side between the elbow and wrist.

FIG. 45.—Bones of arm and hand.

The radius is on the same side as the thumb. When the hand is turned so that the palm is down, the two bones lie across each other.

In each wrist there are 8 short bones. They are, together, called the *carpus*. Just below the carpus are the five *metacarpal bones*, and then the *phalanges*. Each finger has three bones, and the thumb, two.

FIG. 46.—The carpus.

Bones of the leg and foot.—The bones of the leg and foot are much like those in the arm and hand, but they have different names. Naming them from the hip down, they are:

1 *femur*, between the hip and the knee.
2 *tibia* and *fibula*, between knee and ankle.
7 *tarsal bones*, in ankle.
5 *metatarsal bones*, in body of foot.
14 *phalanges*, in toes.
1 *patella*, the knee-pan.

FIG. 47.—Bones of leg and foot.

This makes 30 bones in each leg.

The femur is the largest bone in the body. At its upper end it is jointed to the hip-bone, and at its lower end to the tibia and fibula. The tibia and fibula lie side by side between the knee and ankle. The tibia is the shin-bone, and it lies on the same side

as the great toe. In each ankle there are 7 short bones. They are, together, called the *tarsus*. Just below the tarsus are the metatarsal bones, and then the phalanges. Each toe has three bones, except the great toe, which has two.

Other bones.—If you will now count all the bones that have been named and described, you will find you have 184. That leaves 22 to be yet named to make the 206.

FIG. 48.—Hyoid bone.

There are 14 bones in the face. These are of various shapes and sizes, forming a frame-work for the nose, mouth, and cheeks.

There are three small bones in each ear. These will be shown when we explain the ear.

The breast-bone, called the *sternum*, is the bone to which the ribs are attached in front of the chest.

Last is the *hyoid bone*, shown in Fig. 48. It is located at the base of the tongue.

This completes the list of 206 bones.

Why bones are hard.—Bones are made of two kinds of matter. One is called *animal matter*. It is soft and bends easily. The other is called *earthy matter*. It is chiefly lime, and makes the bone hard and strong. About two-thirds of the bone of a man is lime. In some parts of the body, as in the ears and the point of the nose, the lime is left out. It is then called cartilage, and can be easily bent without breaking. The bones of young children are soft because there is not much lime in them.

Experiment 16.—Get, at the butcher-shop, the rib of a lamb. Clean it of all flesh or fat.

FIG. 49.—Bone tied in knot.

Place it in a tall bottle or long dish and cover it with water. Then pour into the water about two ounces of strong hydrochloric acid. Stir or shake it, and then set aside for a day or more. The acid will "eat out" all the lime,

and only the soft animal matter will be left. The rib can then be easily bent or tied in a knot without breaking.

Experiment 17.—Place a chunk of hard bone in the hot part of the fire in a stove or furnace. In two or three hours all the animal part of the bone will be burned out, and only the lime will be left. This part is brittle, and will break if struck with a hammer.

FIG. 50.—Longitudinal section of femur.

Strength of bone.—The mixture of lime and animal matter makes the bones very hard

and tough. The shape of the long bones also increases their strength. As shown in Fig. 50, a long bone is a hollow shaft. This makes them able to bear a great deal of weight without bending. The ends of long bones are larger than the middle part, and are filled with a kind of spongy bone.

The hollow of the shaft is filled with fatty marrow. The strongest bones are placed where they are most needed. The femur, for example, must hold up the body and also heavy weights, which are sometimes carried.

Flat bones, like those in the skull, are strong, because they are made of two plates of hard bone with spongy bone between.

How bone grows.—The bone in the body is alive. It is composed of numerous cells, which build up the bony material. These cells are fixed to one place, and so their food must be brought to them by the blood. In Fig. 51 can be seen the appearance of a very thin cross-section of hard bone as it is seen in a microscope. The round holes at the centre

of the circles are the canals through which blood is distributed to the cells of the bone.

The irregular spots which are arranged in circles around the canals are the bone-cells.

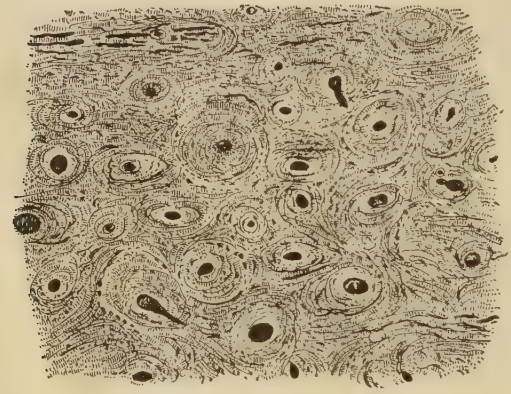

FIG. 51.—Microscopic appearance of a section of bone.

Other very fine canals connect the cells to each other and also to the larger canal at the centre.

All bones are covered with a membrane called the *periosteum*. It adheres closely to the bone, and contains numerous blood-vessels which here and there enter the hard bone and pass along the bony canals.

Care of bones.—Bones may become diseased just like other parts of the body. Good bone cannot be formed unless the blood contains the kind of food that the bones need.

There is a disease called rickets which is common with children whose food is of a poor kind or insufficient. The bones of their backs and legs are often bent and out of shape. The bone-cells are so poorly fed that they cannot make strong bone.

The bones of youth are quite soft, but they gradually grow harder and more brittle until it is not possible to change their shape. The bones of children may be pressed into a variety of shapes, and if kept that way, they will harden and be fixed in that position.

Bow-legs are a common misfortune which might easily have been prevented by proper care in early life, or might have been corrected by proper supports while the bone was yet soft.

Tight shoes will deform the bones of the foot and cause one to walk in an awkward and unsteady manner.

Stooping shoulders come from careless habits of standing or sitting with the shoulders bent forward. The head should be held up and the chest pushed forward. This is desirable, not only because it looks much better, but also because it helps one to breathe better and gives him better health.

Those who sit long in one place should be careful of their position. School-desks should be of such shape and size that the feet may rest on the floor, and the body may not be cramped. It is well most of the time to sit back on the seat and hold the book in the hands, rather than to bend over it.

Broken bones.—If the bones of children were as hard and brittle as those of a man, they would often have broken bones from their numerous falls and tumbles. But even the bones of boys and girls are often broken by accident. In such a case it is necessary to call a surgeon at once and have the bone set. Then it must be kept quiet for five or six weeks until the broken ends grow together

again. It is necessary to have a broken bone set and held in place, or it will be long in healing, and will be crooked when it does heal.

Joints of the skeleton.—If there were no joints in the skeleton, a man would be a very stiff and helpless creature. He might be able to stand, but he could not move. If he wished to lie down, he would have to fall over as a stick of wood falls. But the numerous joints permit a great variety of motions. Count the number of joints in the hand alone, and notice how necessary they are to the work which the hand must do. If the joints of a finger or the wrist should become stiff, the hand would be very much crippled.

Kinds of joints.—The two most important kinds of joints in the body are the *hinge* and the *ball and socket.*

The most common is the hinge-joint. It is used in the elbow, the knee, the toes, the fingers, and, to some extent, at other joints.

They are called hinge-joints because they

allow movement back and forth, like the hinges on a door. The elbow-joint, for example, permits us to move the forearm in and out, but we cannot move it sideways.

FIG. 52.—Hip-joint.

The ball-and-socket joint is used where great freedom of motion is desired. The two best examples are the hip-joint and shoulder-joint. As shown in Fig. 52, the ball is at the upper end of the femur and the socket is in the large hip-bone. This will allow the leg to be moved in any direction.

In the shoulder-joint, the upper end of the humerus fits into a shallow socket in the scapula. This gives the greatest freedom of motion, and the arms can be freely swung in all directions.

There are also several other kinds of joints which are well suited for special kinds of motion.

The *pivot-joint* is like that between the atlas and axis which permits a motion of the head from side to side.

The *gliding-joint* permits a slight slipping of one bone on another, as in the wrist and ankle. These joints are strong and flexible.

How joints are held in place.—Joints are formed by two bones which are joined end to end. The ends are kept to their proper place by strong ligaments which reach across from one bone to the other. In Fig. 53 is shown the ligament that binds the humerus to its place in the shoulder.

This ligament is very strong, and it would take a powerful force to break it.

Other joints are bound together in a similar manner.

How joints are kept smooth.—The hard bones do not touch each other at the joints.

FIG. 53.—Ligaments of a shoulder-joint.

If they did, they would wear down and become rough. The ends of the two bones that unite to form a joint are covered with a pad of cartilage. This is very smooth and tough, and is always moist with a slippery fluid that looks like the white of an egg. It is called *synovial fluid*. It makes the cartilage slip-

pery, and so the joints can be moved without friction.

QUESTIONS.

1. Give four uses of bones.
2. Which use do you think most important?
3. Name four kinds of bones.
4. Give an example of each of the four kinds.
5. Name the eight bones of the cranium.
6. What is a vertebra?
7. How is the canal through the spinal column formed?
8. How many vertebræ in the spinal column?
9. Name the classes of vertebræ.
10. Give the number of each kind of vertebræ.
11. Describe the atlas and axis.
12. What is the shape of the spinal column?
13. What is between the vertebræ? What is its use?
14. How many ribs are there on each side?
15. How are ribs fastened at the ends?
16. Describe the pelvis.
17. Where are the clavicle and scapula?
18. How many bones in an arm and hand?
19. Name and give the number of the five different kinds.
20. Describe the radius and ulna.
21. What is the carpus?
22. How many bones in the leg and foot?

23. Name and give the number of the six different kinds.

24. Which bone is the tibia?

25. What is the tarsus?

26. How many bones in the face?

27. How many bones in the whole body?

28. Name all the bones in your arm as you point to them. In the cranium.

29. Name all the bones you can think of, and count as you go.

30. What are the two kinds of matter in bone?

31. Have you performed Experiments 16 and 17?

32. What makes bone strong?

33. How does a bone grow?

34. What is periosteum?

35. What is the cause of rickets?

36. Why are the bones of young children soft?

37. What causes drooping shoulders?

38. Why should a broken bone be set?

39. What is the use of joints?

40. Name four kinds of joints and give example of each kind.

41. How are joints held in place?

42. What is the use of synovial fluid?

CHAPTER VIII

THE MUSCLES

Movements of the body.—In all kinds of animals there is almost a constant movement of some kind. It may be only in the cells, or of some part of the body, or the whole body. When we try to find out whether or not a body is alive, we look for some movement. If we can feel the pulse, we know that the blood is moving through the body. If we see the chest rise and fall in breathing, we decide that the body is alive. If one moves his hand or foot, we take that as a sign of life.

All such movements of the body are caused by muscles. The bones cannot move themselves, but the muscles which are attached to the bones can use them as levers.

Two kinds of muscles.—The most important muscles are those which are attached to bones. These are called the *skeletal* mus-

cles. They cause the chief motions of the body, such as those of the arms, legs, head, trunk, and so on.

Another kind is found in the walls of the stomach, intestines, arteries, and heart. These are not attached to bones.

How a skeletal muscle works.—That a skeletal muscle may produce motion, it is necessary that it sends be fastened to two pieces

FIG. 54.—Illustration of the action of a skeletal muscle.

of bone which have a movable joint between them. Then, when the muscle contracts and gets shorter, the two bones will be pulled towards each other. All the skeletal muscles work on this plan.

Experiment 18.—Get two sticks about one inch square, one 10 inches long and the other

12. Fasten them together, end to end, with a hinge. Let us call the longer stick the humerus and the shorter one the radius. Then the hinge will be the elbow-joint. Fasten a cord at I, Fig. 54, and pass it through a hole at O. This cord will represent the muscle. When the cord is pulled, the shorter stick is drawn towards the longer one. This illustrates the action of the muscle which raises the hand to the mouth.

How muscles are fastened to bones. —The soft red central part of a muscle tapers

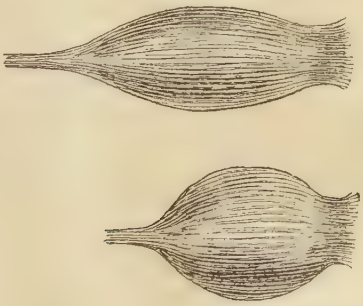

FIG. 55.—Muscle before and after contraction.

off into a very strong white cord called a *tendon*. Beefsteak is the muscle of the ox, and the lean part of pork is the muscle of the hog.

These muscles were used by the animal in moving itself about when it was alive.

FIG. 56.—Muscles and tendons of arms.

Sometimes the muscles are fastened directly to the bone,—that is, they do not have any tendons; but in most cases the muscle ends in a tendon, and then the tendon is attached to the bone.

This arrangement is very nicely shown in Fig. 56. The muscles which move the hand and fingers are placed up in the forearm, and long tendons run from their lower ends down along the wrist to the fingers. This allows the hand and wrist to be small and neat, and at the same time very strong.

A similar arrangement is used for the movement of the feet. The muscles are there placed in the calf of the

leg, and from their lower ends long tendons run down along the ankle to the foot and toes.

The muscles that move the forearm are placed up near the shoulder, around the hu-

FIG. 57.—The biceps.

merus. This muscle is called the *biceps*. It is the one that most boys and men refer to when they want to show how strong they are. You can see in Fig. 57 how it is attached by tendons to the radius at the lower end and the shoulder at the upper end. The lower tendon is bound down close to the elbow. It

is plain that when this muscle contracts (Fig. 54), the hand will be drawn towards the shoulder. These tendons can be easily felt on the inner side of the elbow.

A tendon is so strong that even the bone will be broken before the tendon can be pulled apart. You can see their strength in a butcher-shop where hogs and beef are hung up by the small tendon in their hind-legs.

How muscles are made to contract.— All muscles are made up of a great number of cells, and fine nerve-fibres connect the cells to the brain. When I wish to move one of my fingers, for example, the brain sends an order down along a nerve to a muscle in the forearm. This muscle, then, becomes shorter and pulls on the tendon, causing the finger to move. Such a muscle is called a *voluntary muscle*, because it can be made to contract whenever the mind so wishes. All the skeletal muscles are voluntary. They are under the control of the will, so that we can make them work or rest.

There are also other muscles which are not under the control of the will. They are called the *involuntary muscles*. They are made to contract by nerves also ; but the mind cannot make them rest or work. The heart, for example, beats day and night without any attention of the mind.

The muscles that cause breathing continue their work whether we think of them or not. The muscles in the walls of the stomach roll the food about while it is being digested, though we may give it no thought.

This is a great advantage to us, for if we had to look after all these things, we would have little time for anything else, and would do the work very poorly, besides.

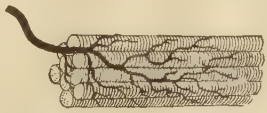

FIG. 58.—Artery feeding muscle.

Structure of muscle.—A muscle-cell may be an inch or more in length, but is so fine that it can scarcely be seen without a microscope. A muscle is a great number of such cells put together in

a bundle. A few cells would have very little power, but when millions of them all work together, they can lift heavy weights and do hard work.

Each cell receives its supply of food from the blood, and when it works, this food is used up. Fig. 58 shows how an artery brings the blood to the muscle. About one-fourth of all the blood in the body is in the muscles.

Muscles of the head.—There are more than 500 different muscles in the human body. They all have names, which are sometimes long and hard to pronounce. We will not try to learn the list now. You can see in Fig. 59 the numerous muscles of the face and neck. When they are made to contract, they cause the various movements of the face and head. We use them in smiling, scowling, sneering, chewing the food, turning the head, and so on.

We will name a number of movements of the head or face, and will ask you to tell by the number in the figure which muscle is used :

1. Turning the head to the left.
2. Throwing the head back.
3. Lowering the chin.

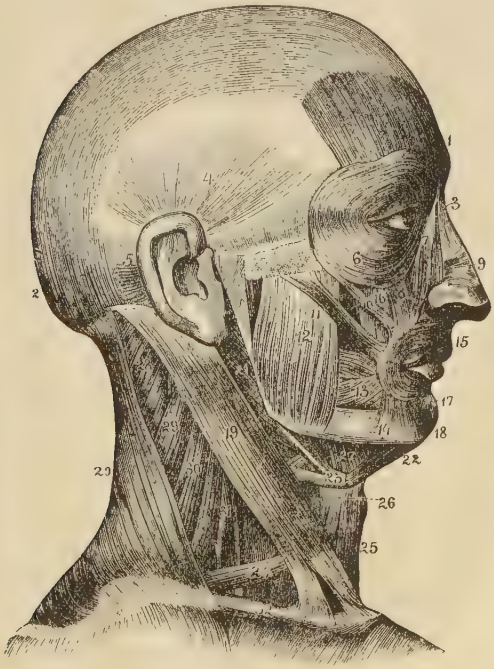

FIG. 59.—Muscles of head and neck.

4. Opening the lower jaw.
5. Closing the lower jaw.
6. Smiling.
7. Sneering.

8. Puckering the mouth as in whistling.
9. Raising the eyebrows.
10. Squinting.
11. Drawing down the corner of the mouth.
12. Moving the scalp.

The use of these muscles has much to do with the expression of the face. A constant scowl may become a fixed expression whether one so wishes or not, and a pleasing expression may as easily become a fixed one.

How muscles are developed.—Muscles grow stronger when they are used. The arm that does the most work is stronger than the other. Any muscle that is unused for a long time will lose all its power. More blood flows to a muscle when it is at work, and so the cells there are better fed.

Each cell is supplied with food and oxygen by the blood, and these two unite in the cell, producing the heat and the ability to do work. So you can see why more blood would have to flow to the muscle that works. It is also plain that good, wholesome food and pure air

are necessary for the development of good muscles.

Development is slow.—A great number of people would like to have strong muscles, and they know the benefit of exercise, but they make a mistake in trying to get large results in a short time. A boy sometimes selects a heavy pair of dumb bells, and thinks he can make large muscles on his arms in a few days. This is all a mistake. All development is very slow, and only those who do just a little every day, and do it right, can expect good and lasting results. It does the muscles more harm than good when they are worked too hard or too long at a time.

Kinds of exercise.—The most of those who work out of doors all day get plenty of exercise, and, as a rule, are strong and healthy. But those who spend most of their time in stores, offices, or as students in school, need to take exercise to keep the body healthy.

The best games for exercise are those that

are taken out of doors in the pure air and sunshine. The best kinds of exercises are those that bring many muscles of the body into use.

Base-ball, tennis, rowing, foot-ball, golf, and similar exercises are all good.

The numerous out-door sports of children are necessary to their growth and development.

A stroll about the town is of little value as an exercise, but a brisk walk through woods and fields is excellent.

The best exercise of all is the physical culture which is taught in the schools. It is best because it is taken every day, and all the important muscles are made to take part.

A trained muscle.—The purpose in many games and exercises is not only to make the muscle strong and healthy, but also to make it skilful.

The muscles of the arm may be very strong and yet very awkward. A strong and large muscle is nothing to be proud of unless it has

been trained so that it obeys the mind. A good writer, a good machinist, a good singer, or a good ball-pitcher are those who know how to do these things, and have practised until they can do them well.

It is a good thing to have strong and healthy muscles, but one's success depends more upon his ability to use them with skill.

A large muscle may be developed often in a few months, but it takes a long time to develop a skilful muscle.

Young people sometimes get in a hurry, and do not see the necessity of keeping up their practice every day, but that is the only way people ever learn to use their muscles with skill.

Effect of alcohol on muscle.—Some people think that beer, whiskey, and other alcoholic drinks will make the muscle strong. They think they can do more work when they take a drink of this kind. This is found to be a great mistake. A great many experiments have been tried, and it is always found

that alcohol will make the muscle less able to stand a long period of labor or exercise.

A drink of whiskey will excite the brain and make one think that he is stronger than he is; he may then start into some work very briskly; but he tires sooner than when he does not drink, and at the end of the day he has less work done.

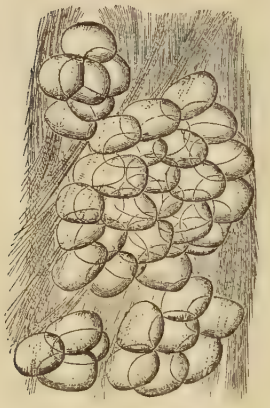

FIG. 60.—Fat tissue.

People who drink beer often get fat, and they look as though they were very healthy, but they are often found to have weak muscles. There is no strength in fat. It is only an excess of food which the body stores up in that form. Beer not only makes fat, but it does so at the expense of muscle. Part of the muscle turns to fat, and, of course, the muscle becomes weak.

It was once quite common to give whiskey

to soldiers before a long march or a battle, but experience has shown that it did the soldier more harm than good. He would "give out" sooner when he drank alcohol. A little sugar is found to do him much more good. The best doctors are opposed to the use of alcohol for such a purpose.

Alcohol and the shops.—A great many men are at work in the great shops and on the railroads. Those who hire these men are always anxious for those who do not drink alcohol. Why is this? There are several reasons. (1) One who drinks does not, as a rule, have strong muscles, and he will get tired long before the whistle blows. Such a one will put in his time, but he will not do as much work as he would do if he did not drink. (2) A drinker is not so skilful in his work. His motions are often awkward and his hand is not steady. (3) Many drinkers will at times get drunk and take a day or more off from their work. This may happen at a time when their employer most needs them. (4) An employer

would rather have men who save their money and have ambition to succeed. They always make better workmen. A drinker wastes his money and time, and loses his ambition to succeed in life. (5) A drinker is not in every way as reliable as one who is sober and industrious.

These are certainly sufficient reasons why an employer prefers a man who does not drink.

The railroad companies are very particular about hiring only those men who do not drink. A single drink is sufficient reason for his discharge. A locomotive engineer must have a steady hand, a keen eye, and must be wide awake. A very slight mistake on his part might cause the loss of many lives and many thousands of dollars' worth of property.

If the railroad companies have found that their men are much better without whiskey, beer, or wine, it would be just as true of men in other kinds of work.

Athletics and alcohol.—Young men who are preparing for some kind of athletic con-

test, such as running, boxing, boating, and foot-ball, often hire a trainer. A good trainer will insist that the boys drink no alcohol and use no tobacco. The reason is very plain. The victory in such a contest usually goes to the one who can hold out the longest,—the one who has the best lungs, heart, and muscle, other things being nearly equal. Whiskey and tobacco will do more harm than any training can do good in preparation for a close contest.

Tobacco and muscles.—It is plain that tobacco never assists in the growth and development of muscle. On the other hand, it often hinders them and works a decided injury. It is often noticed that a boy who uses tobacco becomes lazy. He does not want to be disturbed. He lounges in his seat. He leans against any object near him. He scrapes his feet when he walks and performs his work in a slouchy manner. One reason for this is the poisonous effect of the nicotine on the nerves and muscles.

This is one of the reasons an employer will not hire a boy for work in his office or store if he smokes cigarettes. Any use of tobacco will injure the body and mind of a growing boy, but cigarette smoking is the most harmful of all.

Many investigations have been made of the effect of tobacco on the boys and young men in our schools and colleges. The general conclusion is that the use of tobacco stunts the development of both the mind and the body. Students who constantly smoke the cigar, cigarette, or pipe are shorter in stature and behind their classes in school.

Tobacco smoke decreases the capacity of the lungs and causes an irregular action of the heart. Thus it strikes at the very source of the food of the muscles.

When an employer searches for a boy or young man to take an important position, he always prefers one who does not use tobacco. At least he will make sure that he does not smoke cigarettes. There are other strong reasons why boys should never get into the

habit of using tobacco, but we will give them in a later chapter.

QUESTIONS.

1. What is the common proof that a body is alive?
2. How are most of the body's movements produced?
3. What are skeletal muscles?
4. How do skeletal muscles produce motions?
5. Explain the apparatus you have made for Experiment 18.
6. What is beefsteak?
7. What is the use of a tendon?
8. Where are the muscles that move the fingers?
9. Where is the *biceps?* What is its use?
10. What makes a muscle contract?
11. What are the two kinds of muscle?
12. How do they differ in their use?
13. What is the structure of a muscle?
14. How do muscles get their food?
15. Find 12 muscles in the face and neck (Fig. 59), and tell what they do.
16. How can muscle be developed?
17. What kinds of exercises are good for muscles?
18. What is the advantage of a trained muscle?
19. How does alcohol affect muscle?
20. Give five reasons why an employer would rather hire a man who does not drink alcohol.

21. Why does a railroad company object to a drinker?

22. Why are the boys who enter athletic contests required to abstain from alcohol and tobacco?

23. Give some good reasons for not using tobacco.

CHAPTER IX

THE SKIN

The use of the skin.—The skin covers the whole outer surface of the body. It is tough, elastic, and pliable.

The hair, nails, and teeth are only skin that has been much changed.

The skin is very useful.

(1) It protects the body in many ways, as from poisons, diseases, bites, cuts, scratches, and so on.

(2) Its many nerves send word to the brain at once whenever the body is touched at any point.

(3) It contains many glands that help to take poisonous matter out of the blood.

(4) The water of the sweat is poured out on the surface of the skin and there evaporates. This cools the body when it is too warm.

The two layers of skin.—The skin is formed of two layers. The outer one is called the *epidermis*, and just below it is the *true skin*.

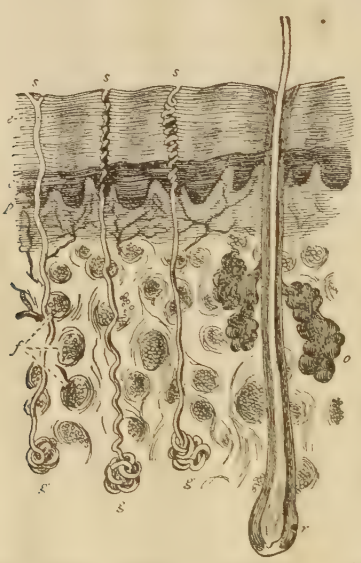

FIG. 61.—Cross-section of skin. *e*, epidermis; *c*, layer which contains the coloring matter; *p*, papillæ; *g*, *g*, *g*, sweat-glands; *r*, root of hair; *o*, oil-glands; *s*, *s*, *s*, sweat-pores; *f*, fat cells.

The epidermis is in most places very thin and nearly transparent. The color of the blood shows through it and gives the skin a pink appearance. The cells of the epidermis are flat and dried. They are not alive like

other cells, but are cemented together edge to edge, as shown in Fig. 62. Several layers like this form the tough epidermis.

Growth of the epidermis.—The outside cells of the epidermis are constantly falling off or are rubbed off by the clothes and by bathing. Other cells are as constantly being added to it on its under side.

FIG. 62.—Cells of the epidermis.

If any part be constantly rubbed or pressed for a long time, the cells will be added in great numbers there. This is what makes the skin in the hand of a workman very hard and thick. The skin is trying to protect the delicate parts beneath it. Corns are produced in the same way by tight shoes.

Color of the skin.—In the lowest layers of the epidermis are placed the little grains of matter that give the color to the skin. These make some people black, others yellow, and others red. In a white skin there is very

little coloring matter. The sunlight may change the color of these grains and "tan" the skin. When the grains are more numerous in spots they are called freckles.

The true skin.—In Fig. 61 it can be seen that the *true skin* contains sweat-glands, roots of hairs, oil-glands, fat, blood-vessels, and is covered with numerous ridges, called papillæ, just under the epidermis.

The chief purpose of the epidermis is to protect the parts beneath it; but the true skin has important work to do.

The papillæ.—Some of the papillæ contain only blood-vessels, and others contain the ends of the nerves of touch. The slightest touch on any part of the body is reported to the mind by these nerves. They are placed very close together on the ends of the fingers and on the palms, and they are there arranged in rows that can be seen with the naked eye.

The fat cells.—Numerous fat cells are found beneath the layer of papillæ. When

they are in abundance, they make the skin smooth and give the face and hands a plump appearance. When the fat is wanting, there is more skin than is needed, and it then lies in folds or wrinkles.

Sweat-glands.—A number of *sweat-glands* are shown in Fig. 61. They are long tubes

FIG. 63.—Sweat-pores in palm of the hand.

coiled up at one end, while the other end opens onto the surface of the skin. These openings are the *sweat-pores*. They are most numerous on the palms and soles. Fig. 63 is a magnified appearance of the rows of papillæ and

the pores from a spot on the palm of the hand.

Perspiration.—The blood circulates through capillaries close about the sweat-glands, and the cells of the gland take from it a great deal of water and several impurities.

This is the sweat which then passes up through the long ducts and oozes out onto the surface of the epidermis. This is going on at all times and is called *perspiration*.

When the sweat dries up as fast as it comes out, we may not notice it; but at other times it comes so rapidly that drops of sweat stand on the surface of the skin. About one quart of water is perspired by the body in one day.

Experiment 19.—Thrust the hand into a cold fruit jar or wide-mouthed bottle and hold it upside down. Let a cold wind blow on the bottle. Drops of water will collect on the inner surface of the glass. The water came from the pores of the skin and was condensed by the cold.

How sweat regulates the heat of the body.—The temperature of the body must be about the same all the time. It must never get much warmer or cooler than 98° Fahrenheit.

The combustion of food in the body is all the time producing heat. Why, then, does the body not become overheated?

The air is nearly always cooler than the body, so that every time we breathe we let out some of the heat in the body. A great deal of heat also escapes from the body, just as it escapes from a hot stove to the air in a room. But when the day is very warm, or when we work or exercise very hard, the body will be heated faster than it is cooled in these ways. Then is when the sweat comes out to help in cooling the body.

A liquid cannot turn to a gas or vapor unless it can get heat. When the water in the sweat turns to a vapor, it must have heat, and it gets it from the warm body. It is not the sweat, but the drying up of the sweat, that makes us cool. Fanning cools the face be-

cause it dries the sweat faster. Fanning would do no good if the skin were perfectly dry. That is why a warm wind feels cool if the skin is wet.

Experiment 20.—Place one of your hands in warm water and then hold it near a register in the draft of hot air. The air will feel cool. The hot air dried the water so rapidly that the hand was cooled instead of warmed.

Experiment 21.—Fan the dry thermometer in your room, and you will find that the mercury will not fall, however hard you may fan.

Now wet the bulb with some water that has been in the room and has the same temperature as the air, or a little warmer. Now fan again, and the mercury will fall. The cooling is caused by the rapid evaporation of the water. The cooling is still greater if alcohol or gasoline is used instead of water.

Experiment 22.—Raise the window a little. Wet one finger in the mouth and hold

it at the opening. If the inner side of the finger feels cooler, the air must be going out. If the outer side, the air must be coming into the room.

In a similar way you can tell which way the wind is blowing when you are out of doors.

How clothing keeps the body warm.—Heat is all the time escaping from the body into the air. When we wear heavy clothes, we keep the heat in, and also check the evaporation of the moisture on the skin. Clothes do not warm the body. They only keep it from getting cold. In hot summer days we wear very light clothing, so the heat can escape.

Hair.—Hairs grow on nearly all parts of the surface of the body. It is thick on the head, and is useful there to protect the head from heat and cold, and from accidental injuries. The eyebrows and eyelashes help to protect the eye, and the hairs in the nose and ears are useful there as guards.

Hairs are a part of the epidermis. They are composed of cells, which are formed at the bottom of the root. The new cells push the old ones ahead of them, and in that way the hair grows.

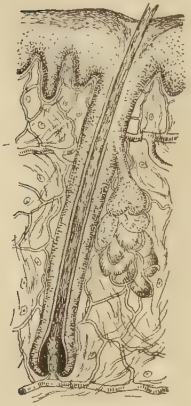

FIG. 64.—The root of a hair.

At the side of the hair, as shown in Fig. 64, are oil-glands. They keep the hair oiled and glossy. The oil also makes the epidermis soft and pliable, so that it may not crack and become chafed.

The nails.—The nails are also a part of the epidermis. The root of the nail is the back part of it where it is attached to the true skin. There new cells are added which push the nail forward and make it grow. The under side of the nail is attached to the true skin, which shows through the transparent nail and makes it look pink.

The free edge of the nail is very useful in many things which we have to do.

The skin is fastened so tightly to the back and sides of the nail that it may be torn by the nail's growth. This causes the "hang-nail," which may become very sore and painful. It may be avoided by pushing the skin back once in a while.

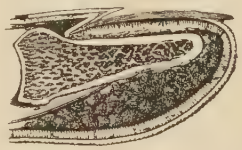

FIG. 65.—A section of the end of a finger.

The free edge often becomes ragged and filled with dirt. They must have proper care two or three times a day. A stiff nail-brush, with soap and water, is good for cleaning the nails, and a sharp knife may be used to trim them when necessary. Dirty nails show careless habits.

Bathing.—Frequent bathing is necessary to remove the grease, dust, and dirt that rapidly gather on the surface of the body. One should bathe and keep his body clean if for nothing else than to make himself agreeable to other people. But bathing is also necessary for the sake of good health. If many of the

pores are stopped, the perspiration is checked. Then the skin cannot throw out the waste and impurities as it should do. A person would become very sick if his sweat-glands would cease their work, or if all the pores were tightly stopped. Often when one feels inactive or is catching a cold, it is a good plan to take some vigorous exercise and keep it up till the skin is wet with sweat.

The impurities that cause the trouble may in that way be thrown off.

The experiment has been tried of covering an animal all over with thick varnish so that all pores were closed. The animal grew sick and died.

These things show that it is necessary to keep the skin clean and in a healthy condition.

The body should be bathed with water and soap about once a week. In hot weather it may be necessary to bathe more frequently, and in cold weather not so often.

It is very convenient if one can have a bath-room provided with a bath-tub where he can turn on hot or cold water. But a good bath

can be had without these things. A basin of soft, warm water and a sponge or wash-rag with some good soap and dry towels are all that is needed for a thorough bath. These are within the reach of every one, and so there can be no excuse for not having a clean body.

Frequent changes of underclothing is also quite as necessary as the bath. Even when the clothing looks clean, it may be full of filthy matter which it has absorbed from the skin.

QUESTIONS.

1. Give four uses of the skin.
2. What are the two layers of the skin?
3. What is epidermis, and how does it grow?
4. What is a corn?
5. Could one have corns on his fingers?
6. Why is the skin of a negro black?
7. What is an albino? (Look in the dictionary.)
8. What does the true skin contain?
9. What is the use of the papillæ?
10. What causes wrinkles in the skin?
11. Describe a sweat-gland.
12. What is perspiration?
13. How much water may be perspired in one day?
14. How can you show that water is escaping from

the hand even when no sweat can be seen? Have you tried it?

15. What is the proper temperature of the body?

16. Name several ways by which heat escapes from the body.

17. How can sweat cool the body?

18. Why does fanning cool the body?

19. Can a dry thermometer be cooled by fanning it? Have you tried it?

20. How can you tell which way the wind is blowing?

21. Does clothing warm the body? What is the use of heavy clothing?

22. Of what use is hair?

23. How does a hair grow?

24. What makes the hair oily?

25. How does a nail grow?

26. What care do nails need?

27. Give some good reasons for bathing.

28. Why should underclothes be frequently changed?

CHAPTER X

EXCRETION.

What excretion is.—Excretion is the process by which waste and impurities are removed from the cells and thrown out of the body.

When wood or coal is burned in a stove, some waste is always formed, which must be carried away so that fresh coal or wood may be burned. The smoke and carbon dioxide are waste which goes up the chimney, and the ashes are collected in the ash-pan.

When food is burned in the cells of the body, waste is always formed, and must be carried away or the life of the cell would soon end.

Lymph.—Lymph is the fluid which surrounds the cells. It is like blood, except that it contains no red corpuscles. When the blood is in the capillaries, the thin liquid fluid

will ooze into the lymph, and the cell is then bathed in the food which it needs. The red corpuscles only give up their oxygen, and then pass on in the current of blood; but the white corpuscles can pass through the walls of the capillaries and move about the cells.

When the cell burns up some of its food, that is, makes it unite with the oxygen, waste

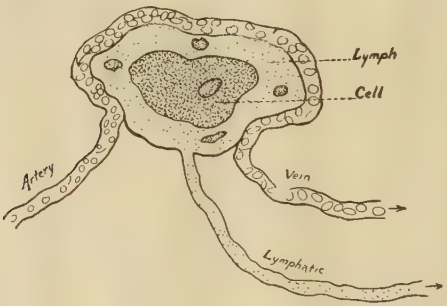

FIG. 66. – Illustration of a cell bathed in lymph. White corpuscles are shown in lymph.

substances are produced which must be carried away. One very common kind of waste is carbon dioxide. This passes out into the blood and is carried back to the heart. So the same stream of blood that brought the

food and oxygen also carries away one of the wastes.

But other waste substances are also produced, and they soon make the lymph about the cells very impure. So there must be some way of draining off the old lymph. This is done by millions of fine tubes called *lymphatics*. They are much like veins and have many valves. They carry impure lymph, while veins carry impure blood.

The fine lymphatics unite and form larger tubes, which pour the impure lymph into large veins in the neck, whence it soon gets back to the heart.

The thoracic duct which we described in digestion is the tube which collects the larger part of the lymph. The lacteals in the villi of the small intestines are a part of this system of lymphatics.

So the waste produced by the cells is carried away by the veins and the lymphatics.

How the impurities are taken out of the blood.—Impurities are brought to the

heart by both the veins and the lymphatics. Unless they are taken out of the blood, it will soon become crowded with waste and poisons. So we find that several organs are at work purifying the blood. The chief ones are the *lungs*, *liver*, *kidneys*, and *skin*.

We have already explained that all the blood is brought back to the right auricle of the heart. Thence it goes to the right ventricle, which sends it to the lungs. While it is passing through the lungs, the carbon dioxide escapes from the blood into the air-sacs and is then breathed out. The lungs excrete carbon dioxide and small amounts of other impurities.

We have already described the liver and the work it does. It is very useful in several ways. One of its important uses is to purify the blood. It gathers up the bile and pours it into the small intestine. Bile is not wanted in the blood, but it is useful in digestion.

The liver also excretes other impurities which would soon poison the cells if they were left in the blood.

The kidneys.—The two kidneys are located in the abdomen, one on each side of the spinal column in the small of the back.

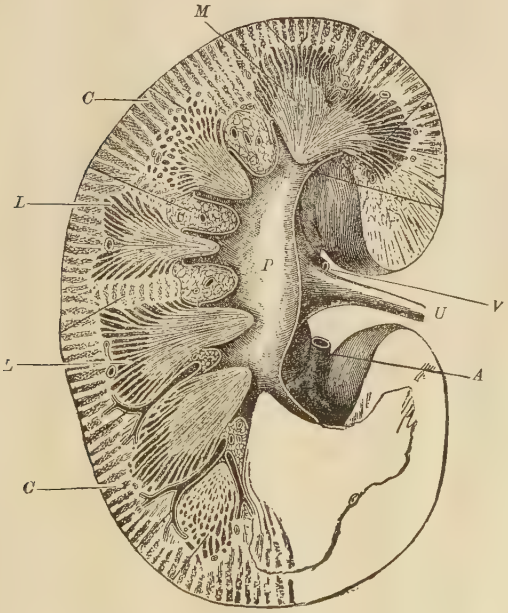

FIG. 67.—Cross-section of kidney. *C, C,* cortex; *M,* pyramids of Malpighi; *L, L,* medulla; *P,* pelvis; *A,* artery; *V,* vein; *U,* ureter.

Each kidney is about four inches long and shaped like a bean.

An artery runs to each kidney and carries

a large amount of blood to them, and a vein from each carries the blood away. The middle tube, shown in Fig. 67, carries off the water and impurities which the kidneys gather out of the blood.

The chief work of the kidneys is to excrete urea. Urea is a waste which comes from the use of proteid food. This kind of food is very important; and it is natural that a small quantity of urea should be present in the blood at all times; but the kidneys must work day and night taking urea out of the blood or the body would soon be poisoned. A man would probably not live more than one day if his kidneys would cease to work.

The skin assists the kidneys, for the sweat-glands not only pour out water, but also some urea and several salts.

Effect of alcohol on the organs of excretion.—We have already explained how alcohol injures the lungs and the liver. Its effect on the kidneys is equally bad. It often changes part of the kidney-cells to fat-cells. Fat-cells,

we have learned, can do no work. So there will be fewer cells to do the work of the kidneys. At the same time alcohol causes more impurities in the body and weakens the organs that try to excrete them. The result is that either the organs are overworked or the blood will be allowed to pass through without being purified.

Alcohol is the cause of nearly all kidney trouble, and nearly all persons who drink a great deal of alcohol have some trouble of that kind. When the kidneys break down, the disease is known as Bright's disease. The skin will then excrete more urea than usual, but it cannot do all the work of the kidneys, and so the blood soon fills with poison and death is almost sure to follow.

There is no organ of the body that is not weakened by the continued use of alcohol.

QUESTIONS.

1. What is meant by excretion?
2. What waste is formed when coal is burned?
3. What is lymph?
4. How does lymph differ from blood?

5. How is the carbon dioxide removed from the lymph?

6. How is the impure lymph drained away from the cell?

7. How are lymphatics like veins?

8. Where is the impure lymph taken?

9. Name four important organs that take impurities out of the blood.

10. What part do the lungs do?

11. What part does the liver do?

12. Describe the kidneys.

13. What is the chief work of the kidneys?

14. What is urea?

15. What does the skin excrete?

16. How does alcohol injure the kidneys?

CHAPTER XI

THE NERVOUS SYSTEM

Parts of the nervous system.—The nervous system is composed of five important parts. (1) One large nerve-centre—the brain. (2) A long nerve-centre in the spinal column—the spinal cord. (3) Many small nerve-centres—the ganglia—found at many places in the body. (4) The nerves which run from the nerve-centres out to every part of the body. (5) Nerve endings, as where a nerve ends in a muscle or gland.

The nerve-cell.—The nervous system is composed of cells just as other parts of the body are, but they are quite different in shape. A nerve-cell in the spinal cord may have to control a cell of muscle in the hand. It must then be able to reach all the way from the cord to the hand. So we find that most nerve-cells have long branches running out from them.

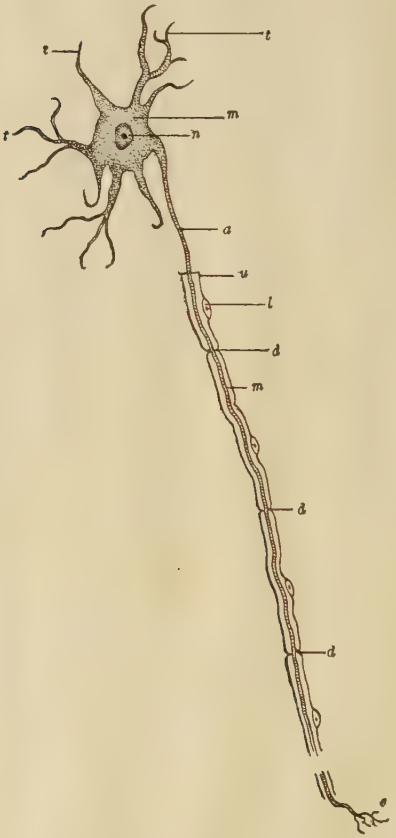

FIG. 68.—A nerve-cell. *m*, body of cell; *n*, nucleus; *t*, short branches; *a*, long branch which runs to *e*, and is covered most of the way by a white sheath.

As a rule, there is only one very long branch and a number of small ones. In Fig. 68 you can see the parts of a nerve-cell. It has a body and a nucleus, and is composed of the same kind of material as the other cells; but it is different in having the long branch that may reach out two or three feet from the body of the cell to another cell over which it has control. When we use any of the skeletal muscles, we must first send an order out on the long branches of the nerve-cells to the muscle-cells.

When a large number of these cells are clustered together they are called a nerve-centre, and a number of the long branches bound together are called a nerve.

All the nerve-centres are in the brain, the spinal cord, and the ganglia.

Everything we do and every movement we make starts in the nerve-centres.

The brain.—The brain is the most important part of the human body. It is very delicate and easily injured, and so we find it

well protected. It is enclosed in a strong, bony box called the cranium. The flat bones of the cranium are quite thick and strong, and will bear a heavy stroke or pressure without breaking.

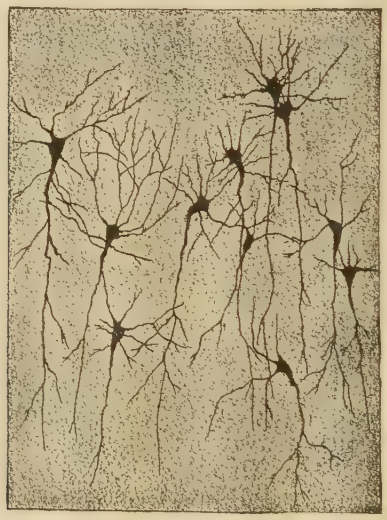

FIG. 69.—Nerve-cells from the brain.

The brain of man is larger in proportion to the size of his body than that of any other animal. The brain of man is not only large, but it is also fine in quality; so that man is the most intelligent of all animals.

The average weight of the human brain is about three pounds. Some weigh as much as four pounds or more, but the most intelligent man does not always have the largest brain. An average sized brain of good quality is better than a large brain of poor quality.

The brain is composed of a great number of cells similar to the one shown in Fig. 68. Several are shown in Fig. 69. A large cluster of cell-bodies have a grayish appearance, and so they are called the gray matter of the brain. The long branches covered with the white sheath is called the white matter.

The brain is divided into four important parts, called the *cerebrum*, *cerebellum*, *medulla oblongata*, and the *pons*.

The Cerebrum.—As may be seen in Fig. 70, the *cerebrum* is much the largest part of the brain. It occupies the whole of the cranium above the ears. Its weight is about two-thirds of the weight of the whole brain. You can see only the right side of the brain in

Fig. 70. The brain is double, and the two sides are just alike. The two halves of the cerebrum are called the *right* and *left hemispheres*. They are connected by fibres which run across from one side to the other.

The surface of the cerebrum lies in folds

Fig. 70.—The parts of the brain.

called *convolutions*. These greatly increase the area of the surface.

The gray matter of the cerebrum is on the outside. It varies from about one-sixth to one-twelfth of an inch in thickness and runs in and out on all the convolutions, as shown

in Fig. 71. The gray matter is the most important part of the cerebrum, for it is made up of the bodies of the nerve-cells.

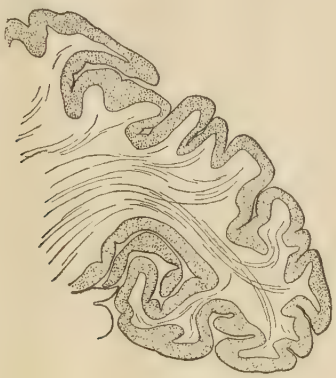

FIG. 71.—Section of cerebrum showing gray matter on outside.

Under the gray is the white matter, which is composed of bundles of white nerve-fibres running down from the cells of the gray matter.

The cerebellum.—The *cerebellum* is the small brain in the back part of the head, below the cerebrum. It is composed of the gray and white matter, and is divided into two equal halves, which are connected to each other by many fibres through the *pons*.

The medulla oblongata.—The *medulla oblongata* is the part of the upper end of the spinal cord that is inside of the skull.

This is a very important part of the brain, as we will show later. It is also divided into two equal parts and contains both white and gray matter. The nerve-fibres from the brain pass over to the other side in the medulla. So the left hemisphere of the cerebrum sends nerves to the right side of the body, and the right hemisphere to the left side.

Nerves.—Nerves are the paths along which messages are sent out from the nerve-centres to all parts of the body, and by which messages are received from all parts of the body.

They are smooth, white, glistening cords, being a bundle of the very fine nerve-fibres which are the long branches from the cells. Nerves are of many different sizes. Some are so small that they cannot be seen with the naked eye. The largest one is the great sciatic nerve which runs down the back part of the thigh. It is a broad band about two-thirds

of an inch across. Branches from it are distributed to the muscles of the legs and feet.

Two kinds of nerve-fibres are bound up in the same nerve. One kind is called *efferent*. They carry messages out from the nerve-

FIG. 72.—Cross-section of a nerve, showing numerous nerve-fibres bound together.

centres. The other kind is called *afferent*. They carry messages into the nerve-centres.

The efferent nerves are called *motor* because we use them in moving the muscles. The afferent nerves are called *sensory* because we use them in receiving sensations.

Twelve pairs of nerves run from the brain to the various parts of the face, head, and body. They are called *cranial nerves*.

Thirty-one pairs of nerves run from the spinal cord out over the greater part of the body. They are called *spinal nerves.*

The spinal cord.—We have already explained that the holes through the vertebræ, when placed one above the other, formed a

FIG. 73.—Cross-section of the spinal cord. W, white matter; G, gray matter; A, front part.

long tube running through the spinal column. Within this is the *spinal cord.*

The cord of the adult is about 18 inches long and about one-half an inch in diameter. It, like the brain, is very well protected from injury.

A cross-section of the cord, Fig. 73, shows that it is composed of gray and white matter, but the white is on the outside and the gray inside.

A deep groove, before and behind, nearly divides the cord into two equal halves. A narrow isthmus connects one side with the other.

The white matter is composed of a great number of nerve-fibres running up and down the cord. The gray matter is composed of nerve-cells. The appearance of the gray matter in the section of the cord is something like the letter H.

Spinal nerves.—Numerous nerves branch off from the sides of the spinal cord. They are called *spinal nerves*, and there are in all 31 pairs of them,—that is, 31 nerves from each side.

In Fig. 74 you can see how they start from the cord, though only one pair is shown in this figure.

Those that start on the front side of the

cord, on both sides of the deep groove, are motor nerves. We use them when we wish to move the hand, feet, or other parts of the body that are not controlled by cranial nerves.

FIG. 74.—A piece of spinal cord. *A*, *A*, anterior, motor, or efferent nerve-roots; *P*, *P*, posterior, sensory, or afferent nerve-roots; *G*, *G*, ganglia on posterior roots; *S*, *S*, beginning of spinal nerves.

Those that start from the back part of the cord are sensory nerves. We use them, for example, when we pass our fingers over any object to see whether it is rough or smooth. If the skin is touched, scratched, or burned, the sensory nerves report the fact to the brain.

These two kinds of nerves soon unite into one bundle and pass out between the vertebræ of the spinal column.

Nerve endings.—The motor nerves run out to all cells where any kind of action is produced. Fine nerve-fibres run to each cell

of a muscle, gland, or other part of the body under control of the nerve-centres. The nerve-cells not only cause all the action in the other cells, but they also regulate the action so it will not be too fast or too slow. Such nerve-fibres end in the cells which they operate.

The sensory nerves often have very complex organs at their ends, so that a very slight disturbance there will be reported to the brain. The eye and ear are such organs, and there are also organs of touch, taste, and smell, making the five special sense organs which are described in the last chapter.

Sympathetic nerves.—Most of the nerves that we have described are operated by the great nerve-centres in the brain and spinal cord. But in addition to these there are also many other nerves which are not under the direction of the will. They do their work whenever it is necessary, and we may know nothing about it. The beating of the heart, breathing, digestion of food, and so on, are all

caused and regulated by sympathetic nerves. These nerves are called sympathetic because they make the organs they control work in sympathy with each other. When the muscles are made to work they need more blood. The arteries get larger, the heart beats faster, breathing is quickened, and the stomach tries to supply more food. This is what is meant by working in sympathy. Each organ is dependent on the others, and there must be some arrangement of this kind for the good of all.

What the cerebrum does.—The size, shape, and quality of the human cerebrum is the chief difference between the brain of a man and that of a horse, dog, or monkey. The human cerebrum is not only larger in bulk, but it has more and deeper convolutions on its surface, and so a greater number of cells in the gray matter.

All mental operations are performed in the cerebrum. It is there that we think, study, solve problems, and commit to memory.

It is in the cerebrum that we make up our minds to do anything, that is, use our will power.

The cerebrum is the centre of all sensation. We cannot know, for example, that the foot has been touched until a message has travelled all the way from the foot to the head and has made an impression on the cerebrum.

A division of labor among the cells of the cerebrum.—The act of thinking is performed by all the cells of the cerebrum acting together, but certain groups of cells have different work to do both in sending out orders and in receiving sensations. Many experiments have been made to find out just what part of the brain moves the fingers, toes, legs, arms, and so on. Also to find what part receives sensations from the eyes, ears, tongue, nose, skin, and so on. Many of these spots are mapped out and are located as shown in Fig. 75.

The areas that cause motion are called *motor areas*, and those that receive sensations

are called *sensory areas.* If any of these motor areas are injured, the part of the body that it controls will be paralyzed and helpless. If the whole right hemisphere of the cerebrum

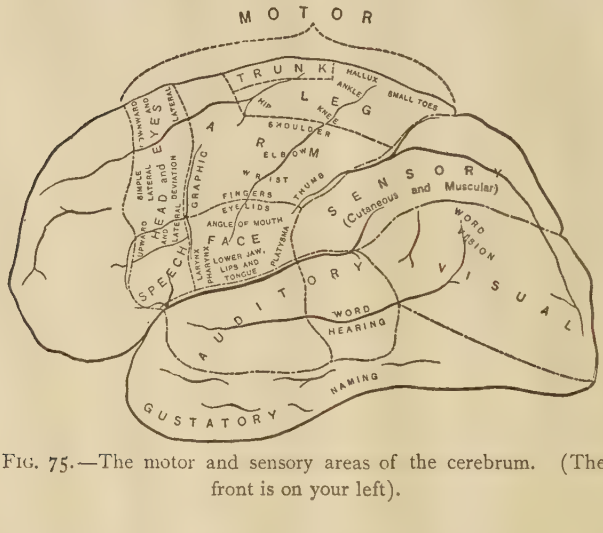

FIG. 75.—The motor and sensory areas of the cerebrum. (The front is on your left).

should be injured, the whole left half of the body would be helpless and without feeling. If any sensory area should be injured, the part of the body from which sensory nerves come to it would be numb and without any feeling. The part could then be cut or burned without any pain.

Use of the cerebellum.—The chief use of the cerebellum seems to be to balance the body. When the cerebellum is injured, the cerebrum can still cause the muscles to contract, but their action will be uncertain and irregular. When such a person attempts to walk he will stagger and sway from side to side. He cannot even stand without some support.

From such experiments, it appears that the cerebellum has the power of regulating the contraction of muscles and making them work together in just the right way to produce the motion we wish. A man can strike just as hard without a cerebellum, but he cannot be sure of hitting what he strikes at.

Use of the medulla and cord.—The white matter of the medulla and cord is composed of numerous nerve-fibres which run to and from the brain. They carry messages to and from the nerve-centres, chiefly the great nerve-centre, the cerebrum ; but the gray matter in the medulla and cord are also nerve-centres of great importance. An injury to the

medulla will cause death more quickly and surely than a similar injury to any other part of the body. A bullet may pass through the cerebrum without causing death, but death follows instantly when any violent injury is done to the medulla. This is because the gray matter in the cerebrum operates several organs upon whose action life depends. Breathing is caused by a centre in the medulla. If this centre is injured, breathing will cease at once. It is even stronger than the cerebrum, for, although we may stop breathing for a time, it will soon begin in spite of any effort of the will.

The medulla also regulates the beating of the heart, making the beats regular and of the proper frequency to supply the blood when it is needed. Sometimes, when the medulla is injured by the use of tobacco or alcohol, the heart will flutter and be irregular in action.

Other centres in the medulla will regulate the size of the arteries, cause coughing, sneezing, or vomiting.

Such work of a nerve-centre is called reflex action.

Reflex action.—When a sensory nerve brings a message to a nerve-centre in the medulla or cord, and the nerve-cells in that centre at once send back an order to a muscle, the action is called *reflex*.

The medulla and the cord are the chief centres of this kind of action. In Fig. 76 can

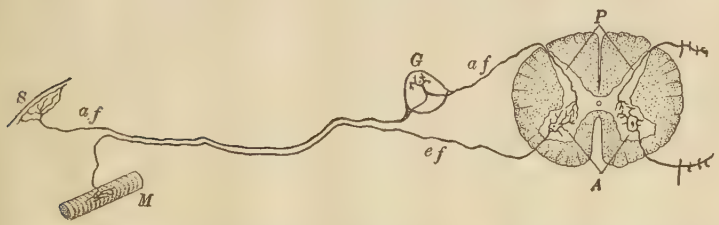

FIG. 76.—Diagram showing the origin and relation of afferent and efferent nerves. *S*, skin; *G*, ganglion; *P*, posterior horns; *M*, muscle; *af*, afferent nerve; *ef*, efferent nerve; *A*, anterior horns.

be seen the path along which a message travels in case of a reflex action. If the hand be accidentally pricked with a pin, or be touched with a hot iron, the sensory nerve will at once report it to the gray matter in the cord, and the cells there will at once send back an order on the motor nerves to the muscles there to pull the hand away.

It is not necessary to wait for an order from the cerebrum, though it may become conscious that the hand has been pricked or burned.

If the spinal cord should be broken in two, the cerebrum could not move the legs ; but if the foot should be tickled, the legs would move and draw the feet away. This would be done by reflex action from the lower end of the cord.

In most cases of reflex action the cerebrum knows nothing about it, and may be entirely absorbed in other matters.

Advantage of reflex action.—If the cerebrum had to give close attention to every little thing we have to do, it would have no time to study, read, write, or think. As it is, the reflex centres will look after most of the details of life after one has grown up.

Education of the reflex centres.—It is possible to educate many reflex centres so that actions which were at first difficult to do may become easy.

Walking is very hard for a child because he must think of every step, but after many trials it becomes a reflex act. He can then walk and at the same time think about something else.

It is difficult at first to make the letters used in writing, but after many trials one can dash off the words without thinking of how he makes them. Some always write slowly and poorly because they have not practised enough to make good writing a reflex act.

It is the same way in learning to ride a bicycle or play on a musical instrument. The lacing and tying of shoe-strings and other little matters of that kind become reflex acts that require no attention of the mind.

It is the duty of every young person to practise doing things that are worth doing until he can do them well even when he is not trying.

Habit.—After one has learned to do anything in a certain way, he will be inclined to always do it that way. It is then said to be a

habit with him. Several repetitions of an act in the same way will soon form a habit.

One who goes "down town" after supper for a number of times soon finds that he has a strong desire to go again whenever supper is over.

One who has learned to tip his hat on speaking will do so without thinking that he does it.

Habits may be good or bad · After a time they become fixed, and are then very hard to change. A good habit is one which leads us to do the right thing even when we do not try.

A bad habit is almost sure to make us do the wrong thing unless we are constantly on our guard.

If boys and girls knew how much every man or woman is a creature of the habits they form in early life, they would be very careful to form good ones.

Every one should be ruled largely by habits, but they must be good ones.

Habits are most easily learned in youth, and after one is twenty-five or thirty years of

age his habits are for the most part fixed. If they are all good, he is very fortunate for life. If they are bad, he will find it very difficult to change them. Even if he does seem to get rid of a bad habit, it will break out in spite of all he can do.

A young man who has formed good habits in speech, writing, conversation, walking, diligence, punctuality, politeness, manners, morality, and so on, has a great advantage over one who has been careless in these matters, and so has bad habits.

Food of the brain.—No part of the body can do any work unless it can get food and oxygen, just as an engine can do no work unless it can get coal and air. When the brain works, it must be supplied with good blood if it is to do good work. A large artery runs up along each side of the neck and carries blood to the cells of the brain. Good, nourishing food and pure air are necessary to make good blood, and so they are necessary to good thinking. About one-eighth of the

blood in the body is supplied to the brain, and if the flow of blood should cease, one would become unconscious at once.

Fatigue of the brain.—Brain-cells become tired just like cells of muscle. Both kinds of cells get from the blood a certain amount of

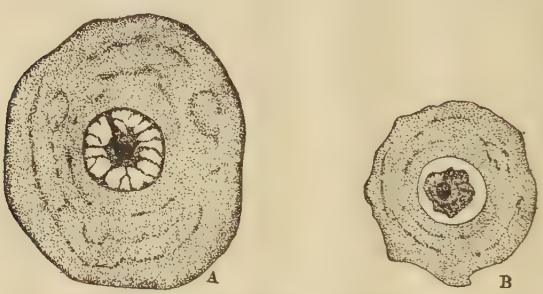

FIG. 77.—*A*, a cell stored with energy-yielding material; *B*, same cell fatigued after a period of work.

energy, that is, ability to do work. When the energy is used up, we say the brain or muscle is tired. When the coal in a steam-engine is nearly all burned and the engine begins to run more slowly, we may say that the engine is tired. When we give it more coal, it is ready to do hard work again. In the same way the brain and muscle become

fatigued or tired because their store of food has been used up ; but if they are allowed to rest until they can be supplied with more food, they will be ready to go to work again.

In Fig. 77 you can see a cell that is well supplied with food. It is round and plump. Below it is shown the same cell after it has been at work and has become tired. It is shrunken because its store of food is exhausted. When it is stored up again it will be ready for more work. So each cell is like a little engine, and can do work only when it is supplied with energy.

Sleep.—The body can get complete rest only when it is asleep. One can get partial rest while he is awake by simply stopping his work ; but several hours of sleep are needed every night that the cells may become stored with energy needed for the work of the day. This is especially true of nerve-cells, which seldom rest except in sleep.

The brain thrives on hard mental work. Like the muscle, it must have exercise or it

will be weak and grow still weaker, but it must have the proper amount of rest.

Amount of sleep needed.—We cannot give any rule as to just how long one should sleep, but when he gets awake he should feel full of energy and ready for hard work of any kind. About eight hours of sleep are needed every night. Most young people get too little sleep, and then try to do a day's work without enough of energy to last them through the day. Such persons make only a sleepy and half-hearted effort in their studies, and do poorly any work they attempt.

No one will ever be hurt by study if he gets the right amount of sleep. The harm is done when we try to force the brain to work when the cells are already fatigued.

The various parties and social gatherings which young people attend cause more bad health than any study they ever do.

They not only lose the early part of the sleep needed, but, after the excitements of the gathering, may have only a restless sleep

during the remainder of the night. They get up feeling tired, and after a hurried breakfast, for which they have no appetite, hasten to school. In such a condition the brain cannot be used long in hard study without doing it injury. Both mind and body may break down under a long strain of this kind, but it is done by lack of rest and sleep and not by over-study.

How to get to sleep.—Most young people in good health can go to sleep as soon as they go to bed. But there are many who do not easily go to sleep, and do not sleep soundly. They do not get complete rest, and so cannot be in perfect health. Such an one should try to get into the habit of sleeping soundly. Here are a few rules about sleeping:

(1) Make sure that the air in the room is pure. Lower one or two windows from the top to get good ventilation. Have no fear of night air; it is just as good as day air. Do not sleep directly in a draft.

(2) Use only enough of cover to keep you

comfortable. Heavy covers will interfere with sleep and cause ill health.

(3) When you go to bed, try to sleep at once. Do not attempt to read or think after you retire. In this way you can cultivate a habit of going to sleep as soon as the head "strikes the pillow."

(4) See to it that the body is clean before retiring. A clean night-dress and clean bed-clothes will also greatly assist in securing refreshing sleep.

Alcohol and the nervous system.—Alcohol has a greater evil effect upon the nervous system than upon any other part of the body. The nerve-centres are very delicate, and for that reason the alcohol shows its bad effect upon them first. When the nerve-cells are injured, all the other cells will also suffer, because the nerve-cells control and regulate the others. For example, alcohol affects the cerebellum, so that it cannot properly do its work. This is the reason a drunken man cannot walk straight, but staggers.

Alcohol has a bad effect on the nerve-cells in the medulla, and so all the organs controlled by the medulla must suffer.

Even if alcohol did injury only to the nerve-centres, still, the whole body would be injured, because all organs depend on the nerve-centres for their direction and regulation.

Uses of alcohol.—Alcohol is very useful in many ways. It is very useful in a drug-store in the preparation of many medicines. Doctors use a great deal in their practice. In the arts and sciences it would not be possible to get along without it. These are all proper uses of alcohol, and it is a great advantage to mankind when used in any of these ways. But when it is used as a beverage, it has done and is doing a great deal of harm.

A beverage is a drink. When people use alcohol as a beverage, they take it as a drink, either because they think it does them good, or because they like it, or have acquired a strong appetite for it and cannot resist the temptation to drink it.

Alcohol as a beverage is not pure, but is contained in such drinks as whiskey, beer, wine, hard cider, and so on.

These have been used as a beverage for a long time; but its terrible effects upon the brain and other organs of the human body were never so well known as now.

Alcohol as a beverage is evil and only an evil.

Effect of alcohol on the cerebrum.— The cerebrum is the organ of thought and the master organ of the rest of the body. When alcohol gets into the body, it is soon carried in the blood to the cerebrum. There it excites the nerve-cells for a time, and some people get the idea that they can think better when they drink some alcohol. But, in fact, alcohol makes the mind have many false notions. When any one drinks even a moderate amount of whiskey or beer, he gets an idea that what he thinks or does is much better than it really is. After the effect of the drink has passed away, he may be ashamed of what he did under the influence of alcohol, and the

cerebrum will be left weaker than if it had received only a supply of pure blood.

A little alcohol.—Every one abhors a drunkard ; but there are many who think that a little alcohol will do the brain no harm. A man may drink a little alcohol and not be harmed, just as he may take a little dose of any poison and not be harmed. But it does more harm than good, and always gives the body some extra work to do to get rid of it.

Even if the body is able to get over it, the tendency of alcoholic drinks is always to do harm.

Then there is also the danger that those who drink only a little will soon drink more and more, until they become drunkards. Nearly all drunkards began by drinking just a little.

Alcohol and warmth.—One of the uses of food is to keep the body warm. This is done by the union of the food with the oxygen, as a stove is heated by the union of the coal and oxygen. Alcohol unites with oxygen and

produces heat. When it is taken into the body, some of it unites with oxygen and produces heat; but at the same time it produces other changes which cause the body to lose more heat than it gains from the alcohol.

Certain nerves regulate the size of the arteries. When the body is exposed to the cold weather, the arteries near the skin will be made to contract and keep the warm blood within the body, so the heat cannot easily get away.

Now, alcohol will to some extent paralyze these nerves, and the blood will be allowed to flow out to the surface of the skin, where the heat can rapidly escape to the air.

The red skin, blood-shot eyes, and swollen nose of an old drinker show that this is a fact.

It is known that one who drinks whiskey on a cold day will freeze much sooner than those who rely only on plenty of food, good air, and exercise to keep them warm.

The safe way.—The only way to be safe from the evil effects of alcoholic drink is to not use it at all. A few drinks of beer or wine may

do no harm as far as we can see; but every drink, however small, makes it easier to take the next and the next, until a habit is formed and an appetite grows. Every drink has its effect and always tends towards excess.

The laws of physiology are the same now as they always have been, and the experience of people in the past all teaches that the only safe way is to totally abstain from the use of alcohol as a beverage.

Opium.—Opium is a strong narcotic poison. A narcotic is a substance that acts on the nerve-centres, making one sleepy and stupid.

Opium is a drug that is obtained from the juice of the poppy plant. It is of great value in medicine.

It is easy to get into the habit of eating and smoking opium, and the appetite for it becomes so strong that it is seldom possible to resist it.

Many people in this country use opium, but its use is most common in China and India.

No drug will so completely wreck both mind and body as opium.

Tobacco.—Tobacco is also a narcotic poison, but its use is not nearly so destructive as that of alcohol and opium.

The chief evil from tobacco lies in the fact that its use is common with boys and young men. Probably the use of tobacco in any form never does any one any permanent good, but the *moderate* use of cigars by grown people who live much of the time out of doors, seems to do no harm.

Boys in school, students in college, clerks in stores, or any one whose work is most of the time in a close room, are greatly harmed by the use of tobacco. The cheapness of the cigarette and its convenience for a short smoke make it the most harmful use of tobacco. The cigarette is always used to excess.

The cerebrum is injured by the use of tobacco in two ways. The nerve-cells there are directly poisoned by the nicotine, and other organs of the body are not able to furnish as pure blood for the nourishment of the brain.

The effect of tobacco on the brain of boys

in school is often very apparent. They are often restless and inattentive; they are not able to keep their minds onto what they are reading; they cannot commit to memory; they fall behind and want to quit school. Tobacco is not the cause of all such failures, but a good scholar may easily be made a poor one by the use of tobacco.

Tobacco not only harms the mind and body, but it makes boys careless in their habits, less polite, and rougher in disposition. This is one reason why boys that smoke are shut out from some of the best positions.

Any boy who will take a sensible view of the whole matter will decide that it does not pay to learn to use tobacco.

QUESTIONS.

1. Name four parts of the nervous system.
2. How do nerve-cells differ from other kinds?
3. What is a nerve-centre?
4. How is the brain protected?
5. What does a human brain weigh?
6. How does gray differ from white matter?
7. Name four parts of the brain.

8. What is the size of the cerebrum?

9. What are convolutions?

10. Describe the gray matter of the cerebrum.

11. Describe the medulla oblongata.

12. What are nerves?

13. How do afferent differ from efferent nerves?

14. How many pairs of nerves are there?

15. Describe the spinal cord.

16. Make a drawing of a cross-section of a spinal cord, and describe the parts.

17. What are the two kinds of nerve-fibres in a spinal nerve?

18. What are sympathetic nerves, and why are they so called?

19. What is the work of the cerebrum?

20. How is the work divided among the cells of the cerebrum?

21. Find in Fig. 75 the group of cells that move the wrist, the thumb, the ankle, the lower jaw, the eyes, and so on.

22. Find the sensory regions of sight, hearing, tasting and feeling.

23. In what part of the head are the sensory regions?

24. What is the use of the medulla?

25. What is meant by reflex action?

26. How is reflex action an advantage to us?

27. Name several kinds of action that are reflex.

28. Name several actions that may be made reflex.

29. What is a habit?
30. How are habits formed?
31. Why is it important to have good habits?
32. Why is the brain supplied with blood?
33. How does study affect the brain?
34. Why is sleep needed?
35. How much sleep is necessary?
36. How is the brain injured by loss of sleep?
37. Give four rules for good sleeping.
38. Name some good uses of alcohol.
39. What is a beverage?
40. Name several alcoholic beverages.
41. How does alcohol injure the cerebrum?
42. Why is a moderate use of alcohol harmful?
43. Show that drinking alcohol is not a good way to warm the body.
44. What is the only safe course in the use of alcohol?
45. What is opium, and how is it used?
46. Describe the evil effects of tobacco.

CHAPTER XII

THE SPECIAL SENSES.

What the special senses are.—The sense of *sight*, *hearing*, *feeling*, *tasting*, and *smelling* are called the *five special senses*. They are called special because there are special organs which help to make the sensation clear and distinct. The eye is the special organ of sight; the ear is the special organ of hearing; the touch papillæ, of feeling; the taste-buds on the tongue, of tasting; and special nerve endings in the nose, of smelling.

Where sensations are made.—Sensations are all produced in the cerebrum, and never in the organ of sensation. Thus we have the sensation of light in the back part of the cerebrum, and not in the eye. The sensation of hearing is also in a region in the back part of the cerebrum, and not in the ear. The same is true of all sensations. Pain

seems to be in the foot, hand, stomach, or other part of the body, but it is only in the cerebrum, which is also able to locate the cause of the pain. If the sensory nerves from the hand to the cerebrum were severed, the hand could be burned or cut without any pain.

The advantage of the special senses.— All of our senses are valuable to us, but part of them are only general, that is, they are not very definite and distinct. They are such as the sense of pain, weight, pressure, temperature, hunger, thirst, fatigue, and illness. The sensory nerves which carry these general sensations have no special organs at their ends.

The sensory nerves of the special senses have very delicate organs, such as the eye and ear, at their outer ends. By means of these organs a very small amount of light or sound, or the faintest touch on the skin, may cause a sensation.

The special senses enable us to get clear and distinct knowledge of things outside of the body.

The eye.—The eye is nearly spherical in shape, about one inch in diameter, and is placed in a bony socket on a bed of fat. It is covered with a tough white coat. In the front is the *cornea*. The cornea is very clear and bulges forward. Just under the cornea is a thin liquid called the aqueous humor. A little

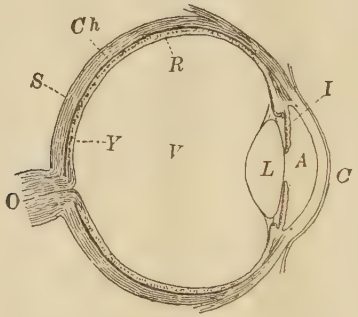

FIG. 78.—Cross-section of the eye. *C*, the cornea; *A*, aqueous humor; *I*, iris; *L*, crystalline lens; *V*, vitreous humor; *S*, sclerotic coat; *Ch*, choroid coat; *R*, retina; *O*, optic nerve; *Y*, yellow spot.

farther in is the *iris*. The iris is a beautiful curtain having in its centre a hole called the *pupil*. The curtain may be drawn back or pulled towards the centre, making the pupil larger or smaller when necessary. Just back of the pupil is the *crystalline lens*. Back of

the lens is a thick liquid called *vitreous humor*. It fills the larger part of the eyeball. The *optic nerve* enters the back part of the eye and spreads out into a thin net-work called the *retina*.

What the eye does.—The purpose of an eye is to make an image of an object and throw it onto the retina. When we look at a tree, the eye makes a small image or photograph of the tree and places it on the retina. This is done by the cornea and lens. If it were not for them, we could not tell a tree from a barn, though we would still be able to tell daylight from darkness. We could not see anything distinctly without the cornea and lens.

Experiment 23.—Secure a small magnifying-glass, a reading-glass, or a pair of spectacles used by some old person. These are all lenses. Hold the lens up near the white wall of a room, opposite a window. Vary the position of the lens till you get a small, clear image

of the window on the wall. Notice that the image is upside down, which is always the position of an image in the eye. Now, change the position so as to get a distinct image of a tree or house outside.

This experiment may be done very nicely with lamps or candles at night.

This shows what the cornea and lens do for the eye.

Use of the iris.—The iris makes the eye very beautiful, but it is also very useful. The iris can make the pupil larger or smaller, and in that way it regulates the amount of light that gets into the eye. We cannot see well if the light is too strong or too dim. The pupil gets large when the light is dim and small when the light is bright.

Experiment 24.—Look into a mirror and notice the size of the pupil of the eye. Shade the eyes with the hands or a screen and notice how the pupils increase in size. This experiment may be performed by suddenly turning the wick of a lamp up and down while you

look into a mirror, or you can easily experiment with the eyes of your friend.

Notice that the pupil of a cat's eye is a narrow slit, which is nearly closed in daytime but is wide open at night.

Use of the lens.—We cannot see distinctly unless the image or picture of an object falls right on the retina. The lens in the eye is shaped like the lens in your magnifying-glass. Both sides are bulged out. But the lens in the eye is soft and can be made to bulge more or less whenever it is necessary. In this way the lens can be made to place the image on the retina. If it were not for the work of the lens, all objects would have to be at the same distance from the eye before we could see them clearly. You can see an object clearly at a distance of two, ten, or fifty feet, but you have to change the shape of the crystalline lens to do so.

Experiment 25.—Look at a window so that you can distinctly see the sash or glass. Keep the eye in that position, and notice that

you can at the same time see a tree or house beyond, but not distinctly. Now look at the tree or house so that you can see them distinctly, and the window will be indistinct. This is all caused by a change in the shape of the lens.

Near- and far-sighted.—The eyes of some people are defective. The lens cannot place the image on the retina of their eyes except at certain distances. Some can see clearly only objects that are near. They are said to be *near-sighted*. The defect can be corrected by wearing concave glasses.

Others can see distinctly only objects that are far away. They are said to be far-sighted. This defect can be corrected by wearing convex glasses.

Even a perfect eye will become far-sighted as one grows older, and that is the reason nearly all old people wear convex glasses.

How the eye is moved.—We can see an object distinctly only when we look straight at it. If the eyeballs could not be moved, we

would have to be constantly turning the head to keep the eyes straight towards an object. This would be very inconvenient. So the ball is provided with six muscles as shown in Fig. 79. They may be made to contract and roll

FIG. 79.—Muscles of the eye. 1, 2, 3, 4, recti muscles; 4 is opposite 2 and cannot be seen in cut; 5, superior oblique muscle; 6, pulley through which the tendon plays; 7, inferior oblique muscle; 8, optic nerve.

the eye in any direction. This is a great advantage in all the small movements of the eye. As in reading, the head may be held still and the eyes only moved.

Sometimes these muscles do not hold the

ball straight and in its proper position. If the inside muscle pulls too much on the ball the eye will be rolled inward. The person is then said to be cross-eyed or squint-eyed. A good oculist can correct this defect and straighten the eyes.

The optic nerve.—An optic nerve runs from each eye to the brain. The retina is one end of this nerve spread out on the inside of the eyeball. The image or picture formed by the eye stops on the retina. From there a message is sent along the optic nerve to the brain. In that way the cerebrum finds out what kind of an image is on the retina. If the visual area shown in Fig. 75 should be injured, blindness would be the result, because no message from the eye could be received.

Protection of the eye.—The eye is a very delicate organ and needs to be carefully protected. The eyeballs are placed in a bony socket, so they are less liable to be injured by accident.

The eyebrows, eyelids, and eyelashes are

on guard all the time to protect the eye from sweat, dust, insects, or other matter that might get into the eye.

The front of the eyeball is always moist with tears to keep it clean and clear.

Tears are made by glands which are found under the skin near the outer end of the eye-

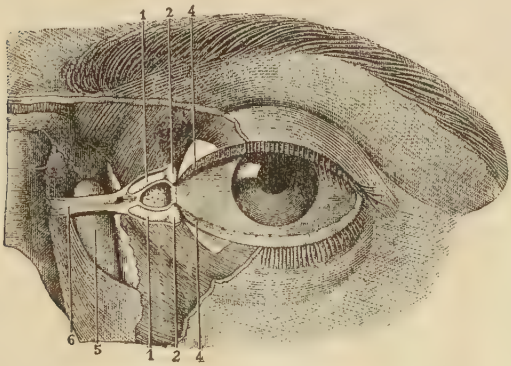

FIG. 80.—The left eye, with a portion of the eyelids removed, to exhibit the lachrymal canals and sac. 1, lachrymal canals; 2, commencement of these on the lachrymal papillæ; 4, edges of the eyelids; 5, lachrymal sac; 6, internal palpebral ligament.

brows. The tears are poured onto the eye at its outer corner and are spread out by winking. At the inner corner of the eye, as shown in Fig. 80, the tears are gathered up by a tube

and carried into the nose. Sometimes, as in crying, the tears come so fast that this tube cannot carry them away and they fall out onto the cheeks.

Care of the eyes.—Every one wants to have good eyes and wants them to be good as long as possible, but some people use their eyes so badly that they do not seem to care whether they go blind or not. Here are a few common rules which should be followed:

1. Do not read fine print.

2. Do not read by a dim light or by direct sunlight.

3. Do not read while riding on a moving train.

4. Do not read while lying on a lounge or after going to bed.

5. Do not bend over a book and look straight down when you read. Hold the book in front of you and about fourteen inches away. If you are near-sighted, it will be well to have glasses fitted to the eyes.

6. The light, if possible, should come over the left shoulder onto the work you are doing.

7. If the eyes pain and smart when they are used, an oculist should be consulted at once before any serious injury is done.

8. Avoid tobacco, for it irritates the eyes and sometimes affects the optic nerve so much that blindness is the result.

9. Keep the whole body healthy and the eyes will share in it.

The ear.—The ear is the organ of hearing. It does nothing but receive sounds and make a report of them to the brain. It is difficult to tell which is our most important sense organ, —the eye or the ear. Both are very important, and it is a great calamity to be either blind or deaf.

The ear is composed of three parts called the *external ear*, *middle ear*, and the *internal ear*.

The external ear is the part that can be seen on the outside of the head, called the *pinna*, and the canal leading in to the middle ear.

The pinna is made of cartilage, and stands out so as to catch the sound and direct it into the canal.

The canal is guarded by hairs and a bitter wax which keep out dust and insects. The wax is secreted by wax-glands and poured into the canal

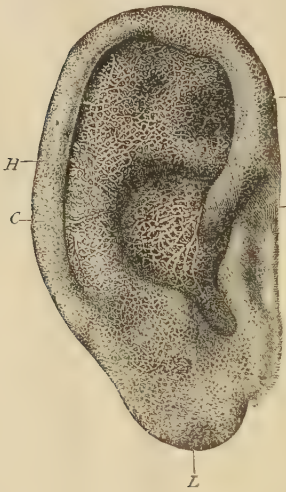

FIG. 81.—Pinna of ear. *H*, helix; *C*, concha; *L*, lobe; *E*, entrance to auditory meatus.

The middle ear is the part marked *t* in Fig. 82. It is a cavity filled with air, and is shut off from the canal by a membrane marked *tm*. For this reason it is called the drum of the ear, and the membrane is called the drum-head. Another canal, marked *eu*, runs from the drum to the throat. It is called the Eustachian tube.

In the upper part of the drum are three little bones marked *h*, *a*, and *s*. *h* is the

hammer; *a*, the *anvil*, and *s*, the stirrup. The handle of the hammer is fastened to the drum-

FIG. 82.—Diagram showing the relative position of the three parts of the ear. *m*, meatus; *tm*, tympanic membrane; *t*, tympanum; *h*, malleus; *a*, incus; *s*, stapes; *o*, oval window; *eu*, Eustachian tube; *sc*, semicircular canals; *v*, vestibule; *c*, cochlea; *F*, fulcrum of the lever formed by the ossicles.

head, and the stirrup is fastened to the internal ear.

The internal ear is an irregular cavity in the solid bone. It contains many winding passages, all filled with a thin liquid which is

nearly pure water. The three upper channels, marked *sc*, are called the *semicircular canals*. The coil, marked *c*, is called the *cochlea*, because it looks like a snail-shell.

The nerve of hearing, called the *auditory nerve*, is distributed in the canals of the internal ear, chiefly in the cochlea.

The path of a sound.—The pinna catches the sound and directs it in through the canal marked *m*. It makes the drum-head vibrate, and the vibration is carried by the three little bones to a small window in the internal ear. There the stirrup vibrates back and forth and shakes the liquid in the internal ear.

This disturbs the ends of the nerves in the cochlea, and they report the disturbance to the cerebrum.

The cochlea is a very delicate and wonderful organ. All the sounds that we hear, and all the beautiful music which we enjoy, are sensations from the cochlea.

Use of the semicircular canals.—The *semicircular canals* seem to be of no use in

hearing ; but they are very useful in another way. They give to the mind its sense of equilibrium, or balance. By this sense we are able to walk or run without falling. This is done by the motion of the liquids in the canals whenever the head is moved.

Care of the ear.—The Eustachian tube connects the throat and the middle ear. The purpose of this is to keep the air-pressure inside the drum, the same as it is on the outside. Often when the throat is inflamed, this tube is partly or wholly closed. Then hearing is not distinct. Sometimes the inflammation may extend into the middle ear and cause serious trouble. Such cases need careful treatment by a good physician.

Sometimes ear-wax will collect on the drum-head and hearing will be dull. It can be removed by a doctor. The wax should not be picked out by means of a pin or other hard instrument.

Insects sometimes crawl into the ear, and it may be very disagreeable to have them there,

but they seldom do any harm. A little warm water or sweet oil poured into the ear will cause them to come out, or they may be taken out with proper instruments.

A loud explosion near by is injurious to the ear. The shooting of cannon or the explosion of large fire-crackers may break the drum-head of the ear.

The sense of touch.—The sense of touch has been partly described in the chapter on

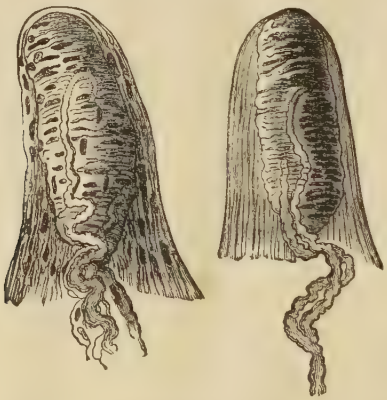

FIG. 83.—Two tactile papillæ from skin of finger. Touch corpuscle within and nerve-fibres below.

the skin. This sense is next in importance to those of sight and sound.

The most important organ of touch is the *tactile corpuscle*, shown in Fig. 83. A great number of these are found in the papillæ of the palms and soles. One or more sensory nerve-fibres end in each one of them.

Other small bulbs at the ends of sensory nerves are distributed throughout the whole skin.

Sense of touch at different points of the body.—The sense of touch is quite acute on the ends of the fingers, and we use this sense to gain a great deal of information.

By placing the fingers upon an object we can tell whether it is rough or smooth, fine or coarse, silk or wool, and so on. Those who buy dry-goods can tell the quality by the sense of feeling.

Blind people read by running their fingers over raised letters.

In a thousand ways we use the sense of touch to gain information.

One of the important uses of the sense of

touch in the skin is to inform the brain whenever the body is touched. In this way the body is often saved from serious accidents and injury.

The sense of touch is most acute on the tip of the tongue; next, on the ends of the fingers; next, on the lips; and least of all on the back.

Experiment 26.—Get a pair of compasses with blunt points, and a ruler divided into inches and parts of an inch. Place the compasses so that both points touch the skin on some portion of the body, say on the back of the hand. Bring the points closer and closer together until you cannot tell whether there are two points or one. Then place the points on the ruler to see how far they are apart, make a record of this, and try a number of other places. You will probably find, for example, that on the ends of the fingers the separate points can be felt until they are only about one-eighth of an inch apart, while on your back they may be as much as two inches apart.

Experiment 27.—Blindfold some one and seat him on a chair. Touch him very lightly at various points on the body, and then ask him to place his finger on the exact spot where he was touched.

This will show how accurately the brain can locate the point from which it received a sensation of touch.

Sense of smell.—The organ of smell is located in the upper part of the nostrils. This is the proper place for this organ, because the gas or fine particles which we smell are in the air. When we breathe, the air is drawn through the nostrils, and we detect any odor which the air contains.

The nerve of smell is called the *olfactory nerve*. It ends in numerous branches in the nostrils, and reports to the brain any odor which it receives.

In ordinary breathing the air does not come in contact with many of the nerves; but by sniffing, the air is drawn up farther into the nostrils, and smelling is much more acute.

Uses of the sense of smell.—The sense of smell gives us often a knowledge of the purity or impurity of the air. When we enter a close room that is poorly ventilated this sense will tell us that such air is not fit to breathe.

It also helps us in the selection of food. The foul odor of rancid butter and decaying meat will be reported at once by the organ of smell.

In some animals the sense of smell is the most important of the five, but in man the two senses, smell and taste, are the least used. They have, however, many important uses, and should be cared for and trained that they may be as useful as possible.

The catarrhal condition of the mucous membrane of the nostrils is destructive to the organ of smell.

The sense of taste.—The sense of taste is a guard placed at the gateway to the stomach, just as smell is a guard for the lungs.

The organs of taste are located chiefly on the tongue. The surface of the tongue looks

rough because of the numerous papillæ upon it. On the back of the tongue are seven large papillæ. These contain the *taste-cells*, and nerves run from them to the brain.

The taste-cells can distinguish sweet, sour, bitter, and salt substances.

If the tongue is dry, there can be no sense of taste. Substances must be in solution before they can get to the taste-cells.

Experiment 28.—Wipe the tongue with a clean handkerchief or towel till it is quite dry. Then at once try to taste a lump of sugar or dry candy. There will be no taste until the tongue becomes moist again. Wipe the tongue again and try some dry salt.

This experiment will show that a substance must be in solution before it can be tasted.

Education of the taste sense.—The sense of taste may be cultivated till it becomes very acute and a safe guide in the selection of food; but the organs of taste may be easily injured so that the sense becomes blunt.

Tobacco and alcohol may so injure the taste-cells that scarcely any sense of taste remains.

A delicate piece of machinery can be kept in good running order only when it is handled with intelligence and care. The same is true of the delicate organs of the human body.

QUESTIONS.

1. Name the special senses.
2. Where do we see and hear?
3. Name several general sensations.
4. Of what advantage are the special senses?
5. Describe the eye.
6. Make a drawing of a section of an eye (Fig. 78) and name the parts.
7. What does the eye do?
8. Of what use is the iris?
9. Have you tried Experiments 23 and 24?
10. What does the crystalline lens do?
11. State what you found by trying Experiment 25.
12. Explain what is meant by near-sighted and far-sighted. What kind of glasses should be used in each case?
13. How is the eye moved? Why is this needed?
14. What is the trouble when people are cross-eyed?
15. How can we know that we are looking at a tree or a house?

16. How are the eyes protected?

17. Tell all you can about tears.

18. Give several rules for the care of the eyes?

19. What are the three parts of the ear?

20. What is the use of the pinna?

21. Describe the middle ear. Why is it called the drum?

22. Describe the internal ear.

23. Describe the path of a sound from the pinna to the brain.

24. What part of the internal ear is most important?

25. What is the use of the semicircular canals?

26. Give some rules for the care of the ear.

27. Where is the sense of touch located?

28. Of what use is the sense of touch?

29. What part of the body did you find (Experiment 26) to be most sensitive to touch?

30. What is the olfactory nerve?

31. What are the uses of the sense of smell?

32. Where are the taste-cells located? Why?

33. Have you tried Experiment 28? What did you find?

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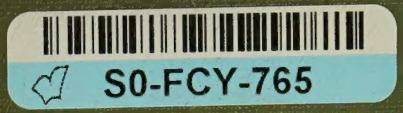
THE END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